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Understanding Urban Travel Growth in the Greater Toronto Area: Volume II

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Understanding Urban Travel Growth in the Greater Toronto Area: Volume II

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Abstract: This report contains an investigation of trip generation relationships within the Greater Toronto Area (GTA) based on 1986 Transportation Tomorrow Survey (TTS) data. Trip rates are examined by purpose, mode, and spatial distribution at the level of the household, the individual traveller, and the zone. In each case, simple models explaining trip generation rates as a function of available explanatory variables are developed. In addition, a measure of "urban density" is developed as a means for categorizing zones into relatively homogeneous groups in terms of their trip generation properties.

Major findings of the study include: relatively simple regression models at either the household or the zone level can be used to represent home-based work and school trip making; non-work trip generation can perhaps be best represented at the level of the individual trip-maker as a function of the person's age, sex and residential location; and a simple "trip-end density" measure provides a useful means of classifying spatial locations as a basis for trip generation analysis.

Comments: Volume II (of 3 volumes) of the final report of Research and Development Branch Project 25194.

Key Words: trip generation, TTS database analysis, spatial variation in trip-making, age-sex variations in trip rates

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EXECUTIVE SUMMARY

The purpose of the research documented in this report is to investigate trip generation relationships within the Greater Toronto Area (GTA) using the 1986 Transportation Tomorrow Survey (TTS) as the database for the investigation. This work represents one component of a larger study funded by the Ministry of Transportation, Ontario (MTO) designed to achieve a better understanding of travel patterns within the GTA as a basis for assessing alternative transportation policies for this large urban area.

The trip generation component of travel demand modelling is often taken somewhat for granted by transportation planners, probably due to the simple modelling methods used and the relatively modest data requirements of these models. Reasonably accurate forecasts of trip generation levels are, however, absolutely essential to the development of credible travel demand forecasts, since these forecasts will obviously be of little use if the absolute level of travel being predicted (and/or the spatial distribution of this travel) is seriously in error. Further, an understanding of the basic factors affecting trip generation rates is essential to formulating transportation policies that will meet the current and future travel needs of urban areas.

The availability of the TTS database provides an opportunity for researchers and planners to re-examine trip generation rates and relationships within the GTA. In particular, several questions or issues exist which can be addressed, at least in a preliminary way, through analysis of this database. These include:

1. what is the most useful/appropriate "unit of analysis" for trip generation modelling (e.g., the person, the household or the zone)?

2. to what extent do trip generation rates depend upon characteristics of the individual traveller (e.g., age and gender) and/or of the traveller's household (e.g., auto ownership)?

3. to what extent do trip generation rates vary spatially (in particular, as one moves from dense, central areas through less dense suburban areas and on into sparse, rural areas within the GTA)?

4. can reliable methods for estimating non-work trip generations be developed that are comparable to work trip modelling methods?

Over and above the detailed findings presented in Chapters 2 and 3, there are perhaps three general results that have emerged from the work documented within this report. These are:

1. Relatively simple regression models at either the household or the zone level can be used to represent home-based work and school trip making.

2. Non-work trip generation is far more difficult to model, given the complexity inherent in non-work travel behaviour. It can, however, perhaps be best represented at the level of the individual trip-maker as a function of the person's age, sex and residential location.

3. A simple "trip-end density" measure provides a useful means of classifying spatial locations as a basis for trip generation analysis.

Consider variability in work trip generation rates exists at the level of the individual trip-maker. Factors influencing this variability include the age and sex of the individual, the modal choices available to the individual, and the individual's residential location (characterized within this study in terms of the "urban density" of the individual's zone of residence). With the exception of the modal choice characteristics, however, the majority of this variability is due to variations in labour force participation rates by age, sex and location, since once the population has been mapped into full-time and part-time workers, very reliable relationships exist between home-end work trip rates and the number of full- and part-time workers, at either the household or the zone level (with, optionally a further disaggregation by gender). Similarly, work-end trip rates can be reliably estimated as a simple function of zonal employment.

Further, changes over time may be more likely to occur with respect to labour force participation rates (e.g., as younger, workplace-oriented women age) and/or full-time/part-time splits within the labour market (e.g., if the trend towards part-time employment, job-sharing, etc. continues) than with respect to worker trip rates per se.[1] Finally, modal choice effects inherently depend on both the trip origin and destination (since it is the combination of these two which determine the modes available for the trip and the modal levels of service offered). Thus, modal choice effects presumably are best handled at a "post-distribution" phase of the analysis, rather than

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[1] Although factors may well exist to alter these rates over time as well. These might include telecommunications impacts that would reduce the need for workers to commute to a central workplace, changes in the number of days either full-time or part-time workers work on average (due to flex-time programs, for example), etc. The strength and timing of such impacts are, however, difficult to ascertain, and certainly to date such trends (to the extent that they exist) have had relatively little impact on the majority of commuters.

within the trip generation phase per se.

For all of these reasons, it appears that a sensible approach to work trip generation modelling involves the following general steps:

1. Predict the number of full-time and part-time workers by sex on a (small) zone basis as a function of the age-sex profile of the resident population and the labour force participation rate distribution expressed as a function of age and sex.

2. Predict the number of 24-hour home-to-work trips produced in each residential zone as a function of the number of full-time and part-time workers (disaggregated by sex, if desired) in the zone, estimated in step 1.

3. Predict the number of 24-hour home-to-work trips attracted to each employment zone as a function of the number of jobs located in the zone.

4. Factor work trips by mode and peak/off-peak periods of travel in subsequent stages of the analysis, preferrably after the trip distribution stage.

This recommended approach has the advantage of being sensitive to demographic changes over time (which have been shown in study after study -- including this one -- to be central to the understanding of trip generation trends), while maintaining a simple, reliable set of trip generation relationships. The major difficulty of the approach, of course, involves generating future age-sex profiles by zone and future labour force participation rate distributions by age and sex. It is suggested that these distributions may be computed by urban density class in a relatively straightforward and (hopefully) reliable way from available data. This suggestion is pursued in detail in Volume III of this report series, in which an operational model of work trip generation based on these concepts is developed and applied to the GTA.

As with work trips, considerable variability exists at the personal level in non-work trip rates as a function of age, sex, modal availability, and spatial location (urban density). Unlike work trips, however, this variability is not successfully "aggregated away" by moving to the household or the zonal level. In particular, household-level regression models manage to explain on 2 to 4 percent of the total variability in household weekday shopping trip generation -- a totally unacceptable result. The one exception to this result is the school trip purpose, for which reliable trip generation relationships at either the household or the personal level are achieved. This is not surprising, given the regular, "work-like" nature of school travel.

For many planning purposes, non-work travel is of relatively minor importance, and hence this component of travel demand is often modelled in a very simple fashion, or else is simply ignored altogether. If, however, one is interested in assessing the overall magnitude of travel within an urban area, then non-work travel certainly cannot be ignored. Given the complexity of non-work travel behaviour, however, and the relatively poor operational models of this behaviour currently available,[2] a suggested approach for modelling non-work travel consists of the following steps:

1. Split non-work travel into three components: home-based school trips, home-based "other" (i.e., non-work and non-school) trips, and work-based "other". This latter category is of importance, since a significant proportion of travel to non-work locations is, in fact, work-based rather than home-based in nature.

2. Generate the home-based trips for school and "other" purposes by mode on a per person basis as a function of the person's age, sex and residential zone density class. This, in turn, requires the generation of zonal population age-sex profiles in the same manner as required for the work trip generation analysis.

3. Generate work-based trips as a function of the total employment in the work zone.

4. If necessary, estimate non-home-based trips as a function of the population and employment located in the given zone.

The combination of modal choice within the trip generation phase (in contradiction of the case just made for avoiding such an approach in the work trip case) is justified partially on the grounds of simplicity but also partially on the grounds that transit usage for non-work travel tends to be more dependent on socio-economic factors and less on level of service considerations (i.e., a higher proportion of non-work transit users tend to be captive to the system) and hence is more readily combined within the trip generation phase of the analysis. It must be recognized, however, that this approach tends to "build in" existing modal split characteristics into forecasts of future travel behaviour to a far greater degree, both conceptually and in practical terms, than the work trip assumption of a separate, post-distribution modal split component.

This suggested approach does, however, provide a mechanism for estimating future home-based and work-based non-work travel with essentially the same inputs as required for the work trip

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[2] A considerable and quite complex theoretical literature exists with respect to non-work travel. In general, however, remarkably little of this literature has been (or can be) applied within practical planning environments.

analysis and in a way which is sensitive to demographic and urban structure changes over time.

Although a quite extensive analysis of the TTS database has been undertaken within the current study, the work to date has in many ways only scratched the surface of what can, in fact, be explored within this database. In particular, promising tasks or interesting research issues that have emerged from the current project include the following:

1. There is a need to conduct a thorough analysis of variance of both person-based and household-level trip generation to complement and extend the analyses presented within this study.

2. The measurement and use of the concept of accessibility as an explanatory variable in trip generation models requires thorough examination.

3. More realistic (yet practical) methods of modelling non-work trip generation need to be developed. One approach to this might involve the development of explicitly probabilistic models of non-work trip generation (in recognition of the inherently stochastic nature of non-work travel processes), perhaps combined within some relatively simple "simulation" algorithm. While this sounds extremely complicated by conventional trip generation modelling standards, it may well be necessary to achieve a significantly improved representation of this important but complex component of urban travel.

4. The relationship between household structure, labour force participation rate, and urban density (and/or accessibility) needs to be examined in more detail, particularly with respect to the extent that this relationship can be expected remain constant over time (or, the extent to which it can be expected to evolve in predictable ways over time).

This report is the second of a three-volume set produced as part of the overall project "Understanding Urban Travel Growth in the Greater Toronto Area". Volume I presents an analysis of the temporal, spatial and modal patterns of work trip commuting into the central area of the City of Toronto, while Volume III uses the empirical results of Volumes I and II as a basis for assessing future travel trends and their implications for transportation policies in the GTA.

CHAPTER 1
INTRODUCTION

1.1 Study Purpose

The purpose of the research documented in this report is to investigate trip generation relationships within the Greater Toronto Area (GTA) using the 1986 Transportation Tomorrow Survey (TTS) as the database for the investigation. This work represents one component of a larger study funded by the Ministry of Transportation, Ontario (MTO) designed to achieve a better understanding of travel patterns within the GTA as a basis for assessing alternative transportation policies for this large urban area.

1.2 Background

The trip generation component of travel demand modelling is often taken somewhat for granted by transportation planners, probably due to the simple modelling methods used and the relatively modest data requirements of these models. Reasonably accurate forecasts of trip generation levels are, however, absolutely essential to the development of credible travel demand forecasts, since these forecasts will obviously be of little use if the absolute level of travel being predicted (and/or the spatial distribution of this travel) is seriously in error. Further, an understanding of the basic factors affecting trip generation rates is essential to formulating transportation policies that will meet the current and future travel needs of urban areas.

The availability of the TTS database provides an opportunity for researchers and planners to re-examine trip generation rates and relationships within the GTA. In particular, several questions or issues exist which can be addressed, at least in a preliminary way, through analysis of this database. These include:

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3. to what extent do trip generation rates vary spatially (in particular, as one moves from dense, central areas through less dense suburban areas and on into sparse, rural areas within the GTA)?

4. can reliable methods for estimating non-work trip generations be developed that are comparable to work trip modelling methods?

The work presented in this report represents a "first cut" at addressing these and similar questions. The results of this investigation then form the basis for thinking about how the level and spatial distribution of trip-making may change in the future as some of the identified factors affecting this trip-making change over time. This latter, more speculative investigation is the subject of the third volume of this report series.

1.3 The 1986 TTS Database

The Transportation Tomorrow Survey is a major transportation survey that was undertaken in the Greater Toronto Area in the Fall of 1986 (mid-September to mid-December). The survey participants were the Ministry of Transportation, Ontario; GO Transit; the Toronto Transit Commission (TTC); and the six regional municipalities within the GTA. This survey is the first region-wide, comprehensive travel survey undertaken within the GTA since the 1964 Metropolitan Toronto and Region Transportation Study (MTARTS). As such, it provides a new and much needed database for the examination of current trip-making relationships within the GTA, as well as for the development of models and other procedures for estimating likely future travel needs within the region.

The TTS database has been extensively documented elsewhere [MTO, 1987a, 1987b, 1988a, 1988b], including a brief overview in Volume I of this report series [Bailey, et al., 1990], and readers unfamilar with the database are referred to these references for more detailed descriptions and discussions of the database. In terms of the work presented in this report, however, key points to note concerning the database include:

1. it provides information on a full range of modes, trip purposes and types of travellers over a twenty-four-hour period for a randomly selected weekday for all members of the households sampled;

2. the validation process has established that work trips are well represented within the database;

3. it is also clear from the validation process that under-reporting exists with respect to non-work trips;

4. only a limited amount of socio-economic information concerning households and individual household members was collected within the survey; and

5. all trip origins and destinations are geocoded to the mid-blockface level, permitting a very precise spatial disaggregation of the data, as well as facilitating the aggregation of the data into any spatial representation desired.

At the time the work reported herein was undertaken, the TTS database was maintained on the Department of Civil Engineering's Sun 3/280 super microcomputer within the EMPRESS/32 Version 2.4 database management system. EMPRESS was thus used to access, manipulate and to export special tabulations of the data, as required by the researchers. These tabulations were then further manipulated and analyzed using a combination of SAS Release 6.03, Lotus Version 2, and Harvard Graphics on an Everex 386 20-megaherz AT microcomputer, S (another statistical analysis package) on the Sun 3/280, and special-purpose Fortran 77 programs on the Sun 3/280.

1.4 Report Organization

In addition to this brief introductory chapter, this report contains three chapters. Chapter 2 presents a detailed analysis of trip generation relationships within the GTA as they are captured in the 1986 TTS database. This analysis includes examinations of trip generation rates on a household, person, and zone basis, as well as examinations of the temporal, modal and spatial variations in these rates. The spatial variation in trip-making propensities is examined in particular detail, given the likely importance of such variations in affecting future travel demand levels as the spatial distributions of people, jobs and activities within the GTA change over time.

Chapter 3 provides a brief review of the recent literature dealing with trip generation, with a particular emphasis on findings from large Canadian cities for which current survey data comparable to the TTS are available. Chapter 4 then discusses the results of the empirical analysis presented in Chapter 2 and of the literature survey presented in Chapter 3 with respect to their implications for trip-making behaviour within the GTA, both in terms of the nature of current travel behaviour and in terms of how this behaviour might be expected to change over time, as well as discusses directions for future work in this area.

This report is the second of a three-volume set produced as part of the overall project "Understanding Urban Travel Growth in the Greater Toronto Area". Volume I presents an analysis of the temporal, spatial and modal patterns of work trip commuting into the central area of the City of Toronto, while Volume III uses the empirical results of Volumes I and II as a basis for assessing future travel trends and their implications for transportation policies in the GTA.

CHAPTER 2
ANALYSIS OF TRIP GENERATION RELATIONSHIPS IN THE GTA

2.1 Introduction

This chapter presents an extensive empirical investigation of weekday trip generation within the GTA, as captured by the 1986 TTS database. In addition to this introductory section, the chapter contains four sections. Section 2.2 investigates the temporal distribution of weekday trip start times by mode, purpose and regional municipality. Sections 2.3, 2.4 and 2.5 then explore a range of simple trip generation relationships using three different "units of analysis" (i.e., the basic unit for which trip generation rates are computed): the household, the individual person, and the zone (in this case, 1979 TARMS zones are used). In each case, particular attention is paid to the extent to which trip generation rates vary spatially within the GTA. In all cases, both work and non-work trip rates are examined. Also in all cases these trip rates are computed on a twenty-four-hour basis so as to measure total trip-making.

2.2 Analysis of Trip Start Times

The start time of each trip made is the only piece of information concerning trip timing available within the TTS database. Figures 2.1, 2.2 and 2.3 present the trip start times for three trip purposes: home-based work trips, home-based school trips, and home-to-shopping trips. In the work and school cases, these are "two-way" trips; for example, a home-based work trip could be either a home-to-work trip or a work-to-home trip. Further, any intermediate stops which might have occurred between the home and work or school destination/origin are ignored. In the shopping trip case, "one-way" trips from home to a shopping destination are recorded, for the first such trip by each household only. In each figure trips are further broken down into auto trips (either driver or passenger) and transit trips (where a transit trip is defined as one which uses at least one transit mode during some portion of the trip). Figure 2.4 provides similar information for home-based work and school trips for the walk and cycle modes combined (where a walk or cycle trip is one in which the traveller makes the entire trip by the given mode). Walk trips for non-work/school trips were not recorded in the survey, and very few shopping cycle trips were recorded, so a walk/cycle distribution for home-based shopping is not included in the figures presented.

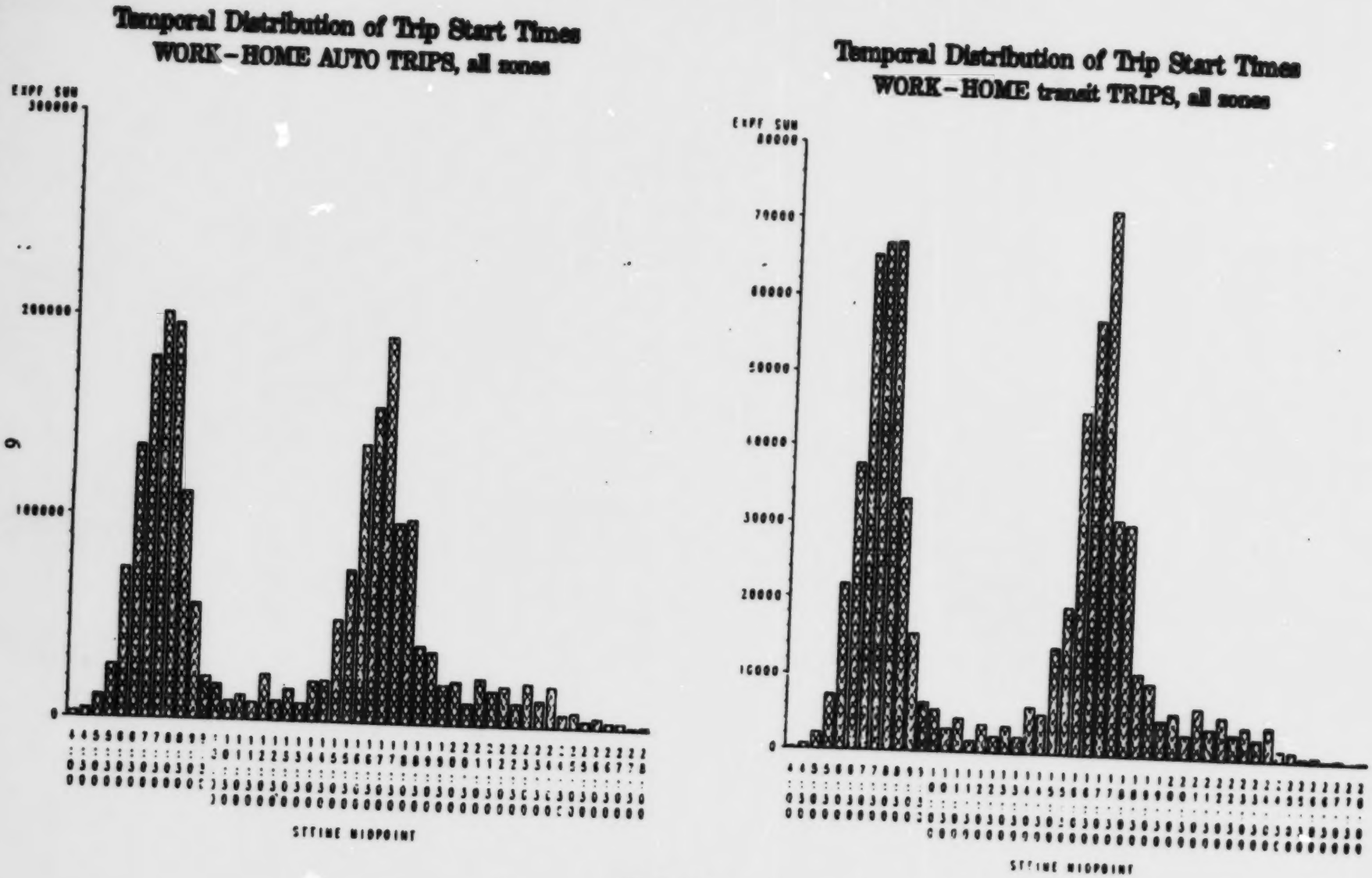


Figure 2.1

Trip Start Time Distribution, Home-Based Work Trips

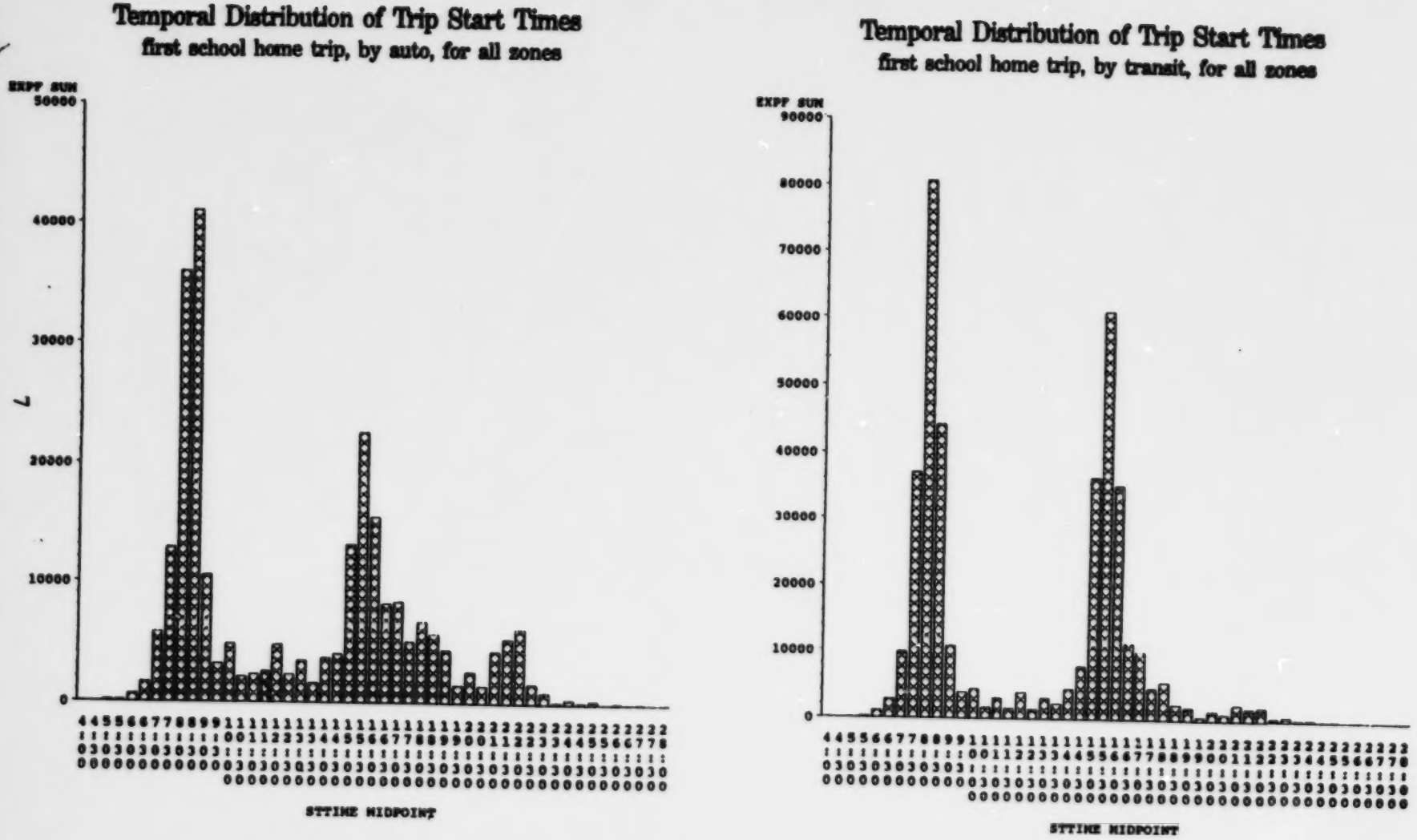
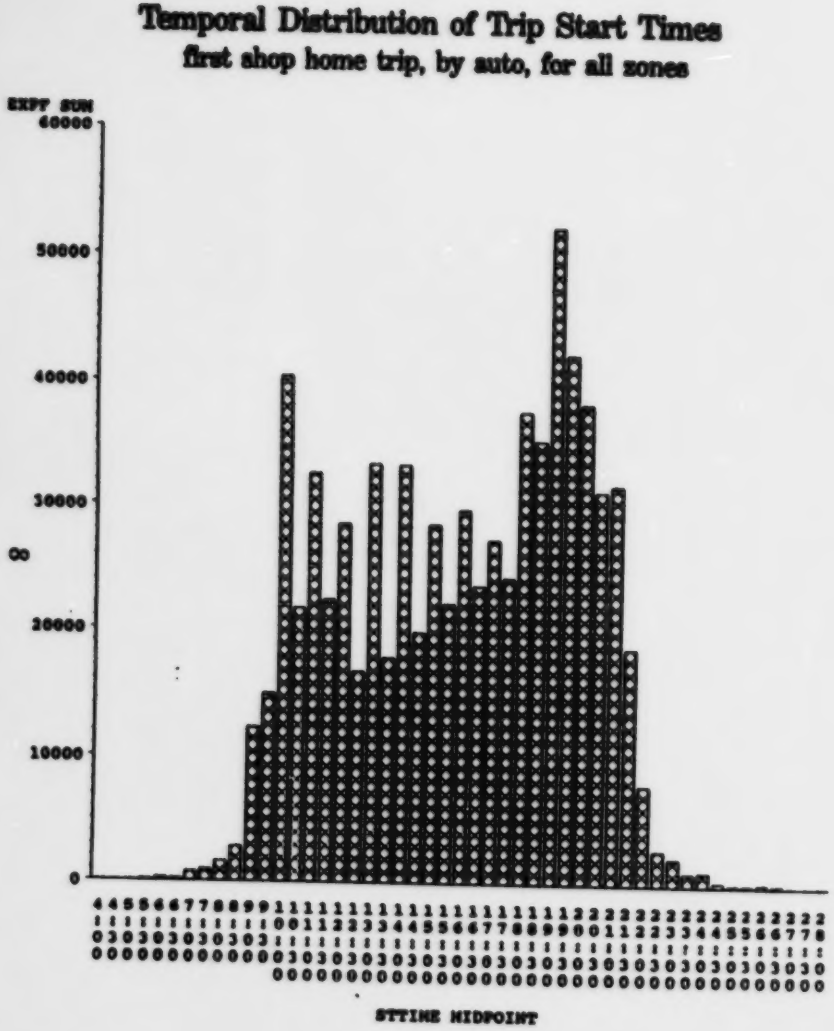


Figure 2.2

Trip Start Time Distribution, Home-Based School Trips



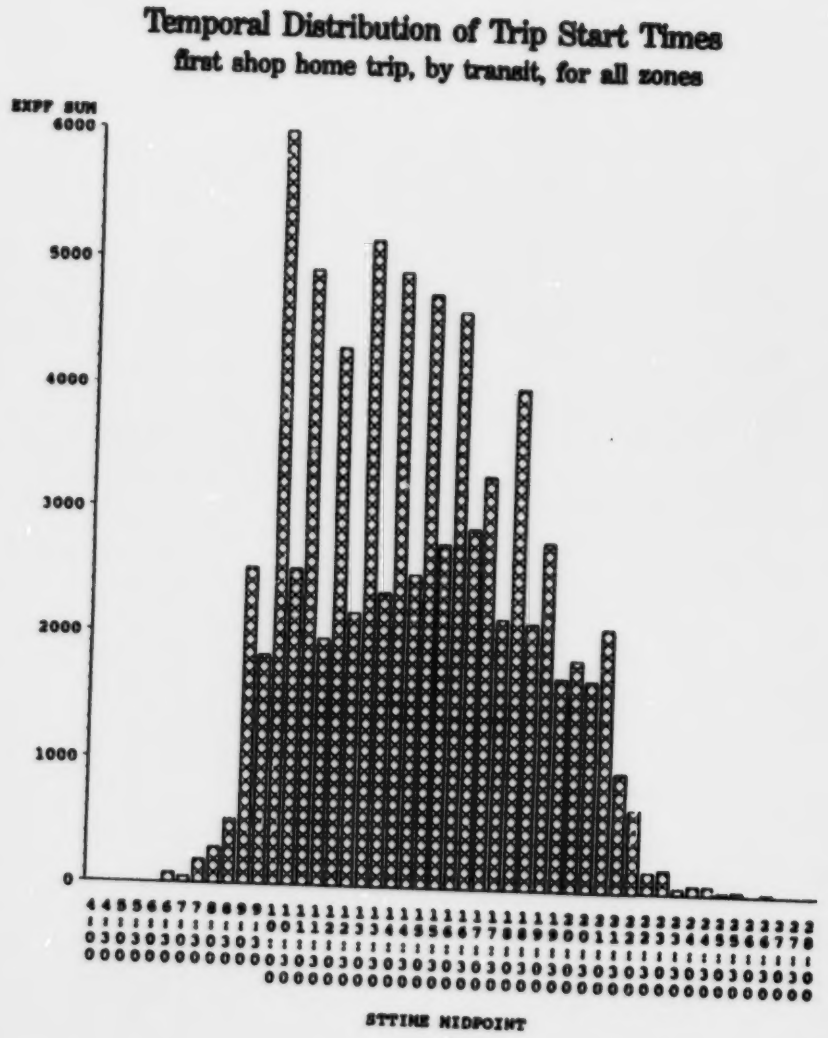


Figure 2.3

Trip Start Time Distribution, First Home-to-Shop Trips

In each of these figures trip start times have been aggregated into one-half hour time slots, centred on the hour and half-hour. Thus, for example, the point labelled 8:30 represents all trips of the given type starting in the GTA between 7:45 and 8:14 a.m., inclusive. This definition of trip start time categories was adopted in an attempt to minimize the effects of respondants' tendency to "round" self-reported start times to "even" time units (e.g., 8:00 versus 8:03). In all cases, the number of trips indicated represented weighted trips, based on the sample weights provided in the dataset. Note that the scales generally change from graph to graph, even within a given figure.

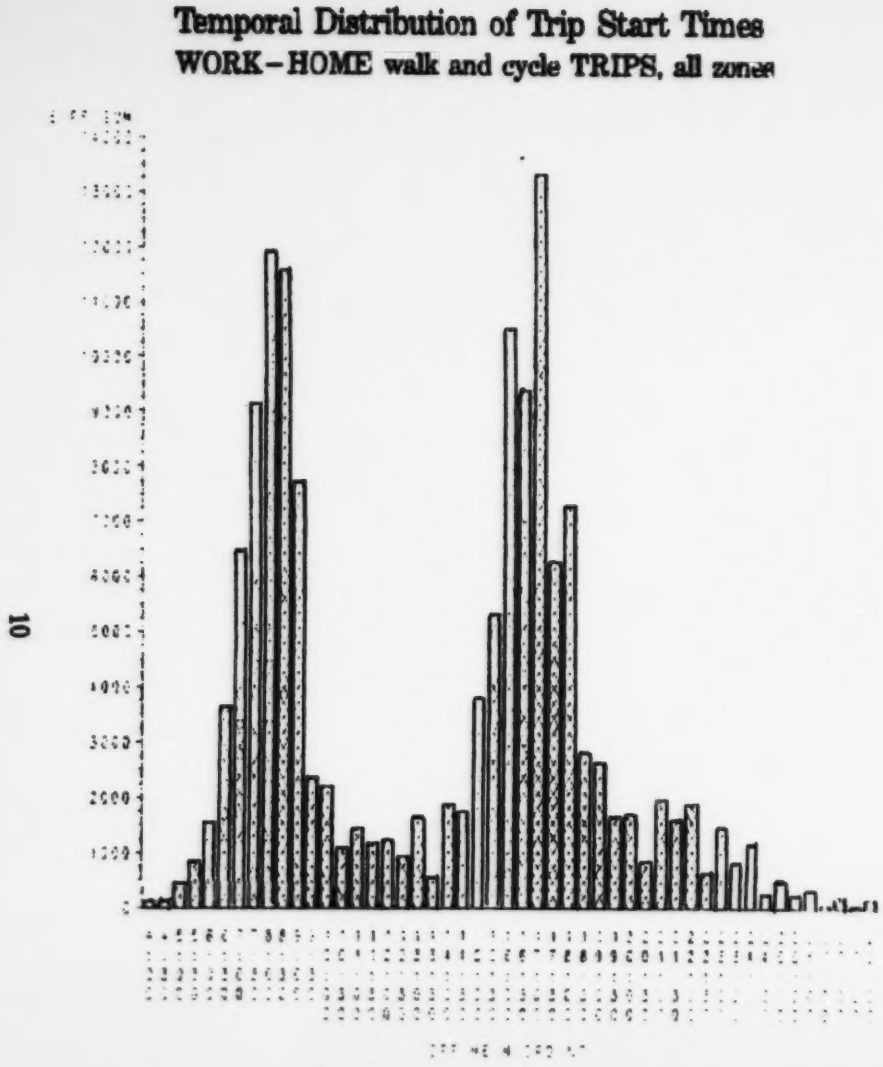
The expected morning and afternoon peaking of home-based work and school trips is very evident in Figures 2.1 and 2.2. In general, the peak travel periods for the auto mode are somewhat more spread than the corresponding transit peak periods, probably reflecting the greater flexibility in trip timing provided by the auto mode. Similarly, school travel is generally more peaked (especially during the morning) than work travel. The histograms are also relatively "smooth" in shape, indicating that there is not likely to be a significant distortion in the start time data due to reporting bias, at least when aggregated into half-hour categories as described above.

Home-to-shopping trips, on the other hand, do not exhibit the two-peak distribution characteristic of the work and school trips. Rather, in the case of auto trips, the frequency of trips tends to grow as the day progresses, with the peak occuring in the early evening (somewhere in the range of 6:30 to 7:30 p.m.). Transit trip-making is even more evenly distributed over the day, with the peak probably actually occuring somewhere around 1:00 p.m. Estimation of actual peaks in the shopping trip case is made difficult by the obvious reporting bias evident in the data, in which respondants appear to be far more likely to report a trip starting on the hour rather than on the half-hour.[1] The effect of adding the home-based shopping trips onto the work and school trips will clearly be a GTA-wide afternoon peak period which is both larger in magnitude and more broadly spread in time than the morning peak period.

The temporal distribution of work and school walk/cycle trips (Figure 2.4) exhibit similar patterns to the auto and transit trips with, if anything, a slightly narrower peak, particularly in the case of school trips.

---

[1] Some of this may, in fact, reflect the way in which people tend to schedule discretionary trips like shopping (e.g., "I'll leave the house by two o'clock to go run some errands"), but it is highly unlikely that this could explain the systematic and extreme differences exhibited between the trips starting "on the hour" versus those starting "on the half-hour".



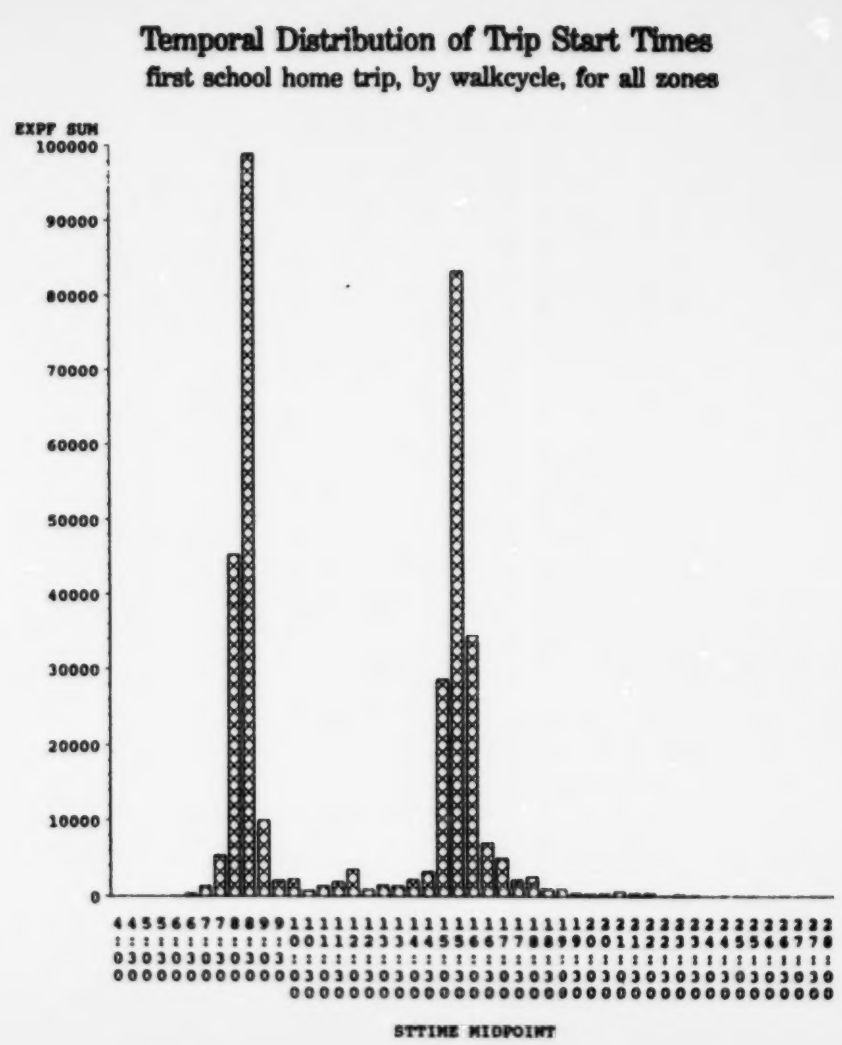


Figure 2.4

Trip Start Time Distribution, Home-Based Work and School Trips, Walk and Cycle Modes

Some variation in trip start time distributions exist among the six regional municipalities, in particular with the morning peak period tending to shift "to the left" (i.e., to earlier start times) as one moves out from central Toronto. Since this is likely to be largely a function of commuting times to central Toronto (i.e., it is not clear why "locally destined" trips should vary dramatically in their start time distributions from one region to another), this issue is explored in more detail in Volume I of this report series, which deals explicitly with travel to central Toronto (see Bailey, et al., 1990, Section 5.2).

In order to explore the nature of the morning peak period (the traditional period of analysis for most travel demand investigations) in somewhat finer detail, Figures 2.5 and 2.6 were generated. In both figures, five minute time categories were defined for the period from 5:00 a.m. to 10:00 a.m., inclusive, centred on the times shown. Thus, for example, "700" on the graph represents the time period from 6:55 to 7:04, inclusive. Figure 2.5 presents start times for "one-way" trips from home to work, school and shopping, while Figure 2.6 presents start times for "one-way" home-to-work trips broken down by mode.

Taken together, Figures 2.5 and 2.6 present a strong case for the need for a three-hour morning peak period, rather than a more traditional two-hour definition. That is, no two-hour definition adequately encompasses the entire peak, whereas a three-hour definition from roughly 6 to 9 a.m. does capture the vast majority of all trips made during the 5 to 10 a.m. period. Further, a three-hour peak is a more "robust" measure, that permits a fair degree of "peak-spreading" to occur over time without having to redefine the peak period, as well as allows for observed inter-GTA variations in local peaking characteristics.

The actual definition of the morning peak period start and end times is always a somewhat arbitrary affair. It is suggested, however, that a definition of 6:00 to 8:59 a.m. (as opposed to a 6:01 to 9:00 a.m. definition) is preferred for the following reasons:

1. Although the number of trips starting at 6:00 a.m. and at 9:00 are nearly the same, the 6:00 a.m. trips are virtually all work and school trips, whereas the 9:00 trips include a greater proportion of shopping trips (and, presumably, trips for other purposes as well). Since peak period models tend to focus on work (and possibly school) travel, inclusion of the 6:00 a.m. trips rather than the 9:00 a.m. trips makes for a slightly "cleaner" set of trips to be modelled.

2. Similarly, the 6:00 a.m. trips contain a higher proportion of vehicular (auto and

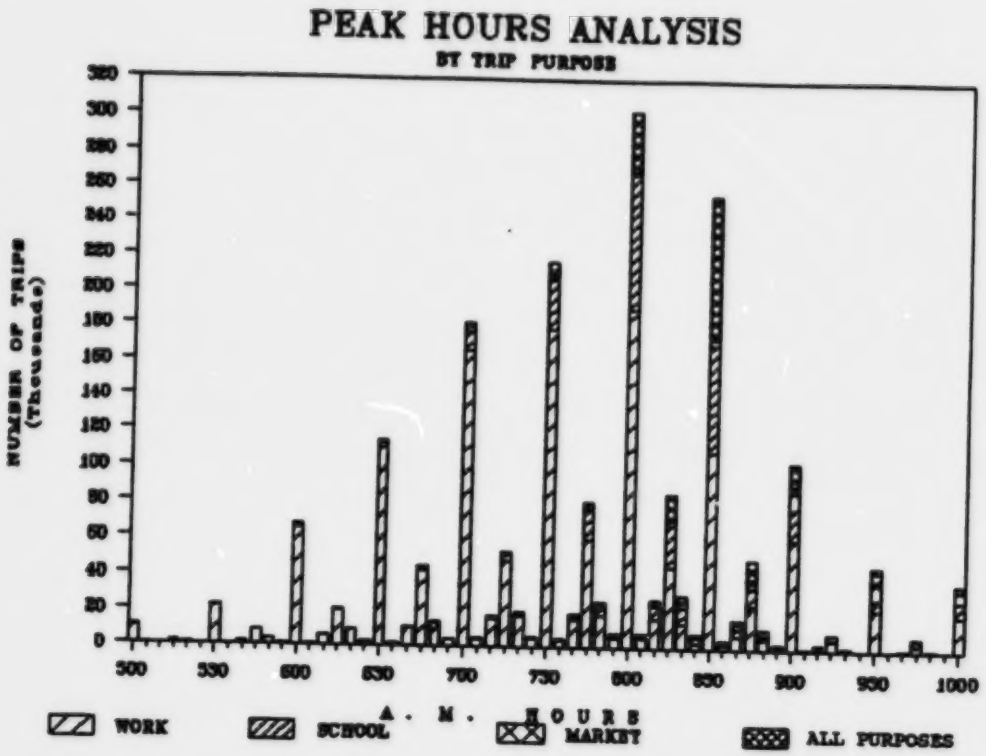


Figure 2.5

Trip Start Time Distribution, Morning Peak Period Trips
from Home by Purpose

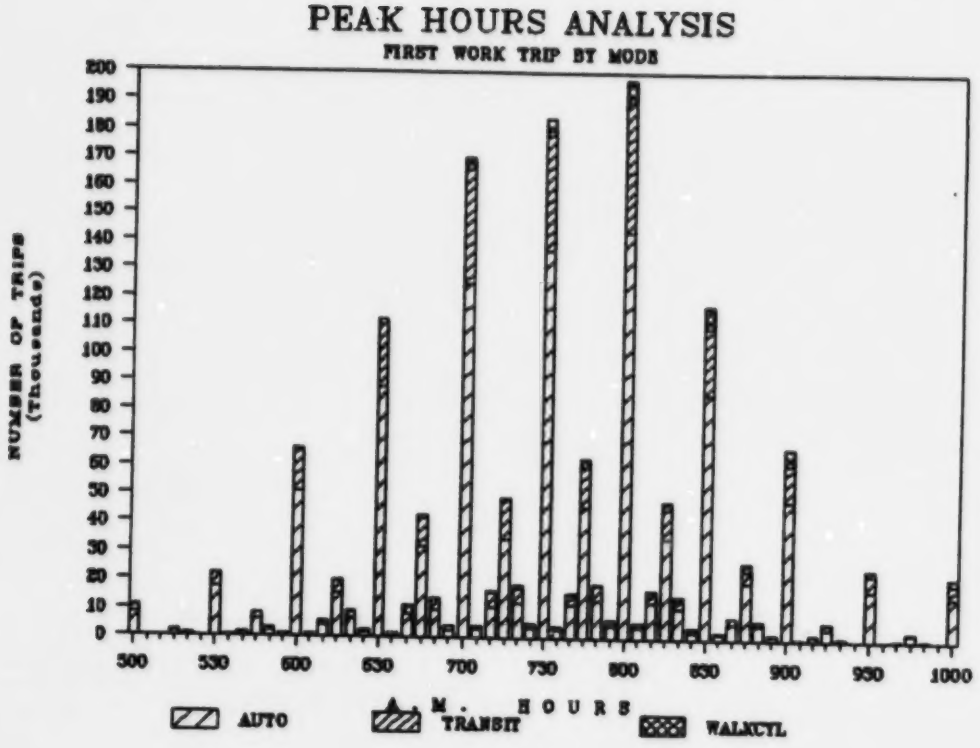


Figure 2.6

Trip Start Time Distribution, Morning Peak Period Trips
Home-to-Work Trips by Mode

transit) trips (as opposed to walk/cycle trips) than the 9:00 a.m. trips. Again, vehicular trips are of primary interest in most travel demand analyses.

3. Trips which begin at 6:00 a.m. clearly will be "on the system" during the morning peak period, while trips beginning at 9:00 a.m. will not.

2.3 Household Trip Generation Rates

One common unit of analysis in travel demand modelling is the household, given that it is the primary sampling unit of travel surveys, many travel-related decisions (e.g., auto ownership level, allocation of usage of household autos among household members, etc.) are essentially household-level in nature, and, in some cases, the household might provide a convenient unit for aggregation up to population totals.

A series of regression equations were developed in an attempt to explain the total number of 24-hour trips generated per household (by purpose) as a function of observed household characteristics.[2] Three trip purposes were considered in this analysis: work, school and shopping.

The number of 24-hour home-to-work trips originating within a given household[3] was regressed against various combinations of the variables, where the selection of potential explanatory variables was based on availability within the TTS dataset, theoretical relevance, and observed correlation with the number of work trips made (as well as observed lack of correlation with other explanatory variables included in the same regression). Variables considered within this analysis included:

- number of male, female and total persons in the household

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[2] For an investigation of the capabilities of linear regression models to capture complex trip generation relationships, see Monzon, et al. [1989]. Their results indicate that linear regression models can be surprisingly robust in their ability to represent trip generation processes which technically violate the statistical assumptions underlying the model. They also indicate that linear regression models can, at least in the case examined, perform as well as far more complex "behavioural" models of trip generation processes.

[3] That is, only trips from home to work (as opposed to trips from work to home) are considered. Throughout this report, "one-way" trips such as this will be labelled in this way; that is, in terms of the origin purpose and the destination purpose (e.g., home-to-work). "Two-way" trips will consistently be referred to in the customary way (e.g., home-based work trips). In the case of work and school trips, both one-way and two-way trips generally ignore the presence of any "intermediate" stops for other purposes (e.g., serve passenger or shop) which might be observed in the trip records.

- number of full-time, part-time and total workers in the household
- number of vehicles in the household
- number of licenced drivers
- the ratio of licenced drivers to persons in the household
- the ratio of vehicles to persons in the household

The variables relating to the number of vehicles and/or number of licenced drivers within the household had negligible significance in explaining household work trip generations. This is not particularly surprising, given the non-discretionary nature of most work trips. The worker-based variables, again not surprisingly, significantly out-performed the person-based variables as predictors of work trip generations. The result of these observations is two regression equations which "best" describe household-level home-to-work trip generation, and which differ only in the level of detail assumed in the explanatory variables:

[1] $HW_h = 0.0851 + 0.781*FTW_h + 0.522*PTW_h$ $(R^2 = 0.560)$

[2] $HW_h = 0.0954 + 0.748*W_h$ $(R^2 = 0.549)$

where:

HW_h = number of 24-hour home-to-work trips generated by household h
FTW_h = number of full-time workers in household h
PTW_h = number of part-time workers in household h
W_h = $FTW_h + PTW_h$ = total number of workers in household h

Equation [1] indicates that, on average, each full-time worker generates 0.781 home-to-work trips per day, while the average part-time worker generates 0.522 home-to-work trips per day, or 66.8% of the full-time worker's average trip rate. Equation [2] indicates that the use of total workers (presumably a simpler measure to forecast) results in an overall fit of the model which is not much worse than the equation [1] fit, but it does require the assumption that the full-time to part-time mix within the resident labour force will remain constant over time. Since this assumption is, in fact, not likely to hold true, equation [1] is preferred for forecasting purposes whenever data on full-time and part-time workers are available.

All coefficients in equations [1] and [2] are statistically different from zero at well beyond

the 99% confidence level. The R^2 values for the two regressions are not overly large, but are acceptable given the use of disaggregate data at the household level. They are also comparable to the R^2 values typically obtained in the literature for household-based models (see Chapter 3). The existence of statistically significant, non-zero intercept terms in these equations is also not overly troublesome, since they clearly are numerically negligible.

Equation [1] was re-estimated for each of the six regional municipalities within the GTA. Table 2.1 provides the results of this more spatially disaggregate analysis. From this table it is seen that, while some variation does exist among the regional municipalities in average trip rates for full-time and part-time workers, this variation is relatively small.

A similar analysis of home-to-school trips yielded similar results, in that of all the relevant variables[4] available to explain school trip productions, the only one of both statistical and numerical significance was the number of students in the household. Thus, the "best" home-to-school trip generation equation found is:

$$[3] \qquad HS_h = 0.0298 + 0.843 * S_h \qquad (R^2 = 0.774)$$

where:

HS_h = number of 24-hour home-to-school trips generated by household h

S_h = number of students in household h[5]

Both coefficients are statistically different from zero at much better than the 99% confidence level, with the intercept term again being numerically insignificant. The R^2 value for the regression is relatively high for a disaggregate dataset and indicates the regularity that exists in school trip generation, even relative to work travel. Similarly, equation [3] also indicates a higher daily trip rate per student (0.843) than that generated by full-time workers (0.781). No investigation of regional differences in school trip generation rates was attempted, since it was expected that, as with the work trips, any such differences would be, at most, small.

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[4] Variables considered included: number of household vehicles, number of male, female and total persons, number of students, number of persons under 15 years old, and number of licenced drivers.

[5] The TTS dataset does not distinguish between full-time and part-time students.

Table 2.1

Household Home-to-Work Regression Results
by Regional Municipality

Region	Intercept	FTW_h	PTW_h	R^2
Metro	0.043	0.782	0.524	0.606
Durham	0.067	0.772	0.568	0.501
York	0.113	0.770	0.479	0.506
Peel	0.085	0.782	0.514	0.502
Halton	0.111	0.788	0.540	0.491
Hamilton-Wentworth	0.061	0.777	0.522	0.548

Table 2.2 presents two models of home-based shopping trip generations, one for the number of 24-hour home-to-shop trips originated by a given household (i.e., trips originating from the household's zone of residence), and one for 24-hour shop-to-home trips (i.e., "return home" trips) destined to a given household. Each model, in turn, has two versions, one in which the number of household drivers is included, and one in which the number of household vehicles is used instead.[6] Dummy day of the week variables are also included in all the models in order to capture systematic differences in shopping trip-making levels across the different weekdays.[7] The following observations can be drawn from this table:

1. Day of the week effects are, in fact, statistically significant, with Thursdays and Fridays consistently generating higher levels of home-based shopping trip rates than the other three weekdays. Friday, in turn, also has a significantly higher trip rate than Thursday. The differences between the Monday, Tuesday, and Wednesday average trip rates are, at most, of minor statistical and numerical significance.

2. Auto availability (measured either in terms of number of vehicles or number of licenced drivers) has a statistically significant positive effect on home-based shopping trip rates.

3. The home-to-shop and shop-to-home coefficients are very similar, indicating that these two trip types could be combined into the more conventional "two-way" representation of home-based shopping trips without loss of information.

4. The explanatory power of the linear regression equations is extremely poor, with only about 3% of the observed variability in home-based shopping trip rates being explained by the regressions.

This last point is, of course, the most important of the four, and considerably reduces the importance one can attach to the other three observations. The simple fact is that linear regression models are almost useless for the prediction of household-level shopping trip generation rates, given that well over 95% of the variation in these rates must be due to factors which are <u>not</u> included within the models.

In order to investigate this issue further, a version of the home-to-shop trip model was re-

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[6] Both variables could not be included in the same model due to their high colinearity.

[7] This is necessary since each household was surveyed on a randomly selected day of the week. Hence, some of the inter-household variation in trip rates could be due to the fact that they were surveyed on different weekdays, rather than due to differences in household characteristics.

Table 2.2

Household Home-Based Shopping Regression Results

Coefficient	Home-to-Shop Trips		Shop-to-Home Trips	
	Model A	Model B	Model A	Model B
Intercept	0.1165	0.1356	0.1640	0.1777
Persons >65 years old	0.2013	0.2006	0.1915	0.1914
# of Lic. Dr.	0.0552		0.0590	
# of Vehicles		0.0542		0.0622
TUESDAY	-0.0126 *	-0.0120 *	-0.0106 *	-0.0099 *
WEDNESDAY	0.0103 *	0.0112 *	0.0121 *	0.0133 *
THURSDAY	0.0518	0.0519	0.0546	0.0547
FRIDAY	0.1209	0.1207	0.1298	0.1297
R^2	0.0369	0.0369	0.0310	0.0320

Notes:

1. The day of week variables equal 1 if the household was surveyed on the indicated day and equal zero otherwise. Each coefficient, therefore, measures the systematic variation in average shoping trip rates by day of the week relative the base case of trips made on Monday.

2. "*" indicates that the variable is not significant at the 95% level for a two-tailed test.

estimated for each of the six regional municipalities. Table 2.3 presents the results from this analysis, from which it is seen that only a marginal improvement in model fit occurs. This table also indicates that Metro Toronto has quite different coefficients than the other regions (which tend to display relatively similar results). In particular, the overall Metro home-to-shop trip rate (as captured by the intercept term) tends to be much smaller than for the other regions, while the number of vehicles coefficient tends to be numerically much larger than in the other regions. Both of these results undoubtedly reflect the absence of walk-mode shopping trips from the sample, which one would expect would be much more prevalent within Metro relative to outside of Metro and hence both bias the overall Metro trip rates downward and tend to accentuate the explanatory power of auto availability.

Thus, while differences exist between regional shopping trip rates, accounting for these differences contributes very little to the overall performance of the model. Another possible factor contributing to the variability in home-based shopping trip rates could be the extent to which multi-stop "trip chaining" occurs (i.e., as more stops per trip that occur, possibly fewer home-based trips are generated). Figures 2.7 and 2.8 provide some indication of the nature of shopping trip linkages, by showing the percentage breakdowns of origins for shopping trip destinations and of destinations for shopping trip origins, respectively, for the six regional municipalities. The origin-destination stop purpose combinations for Metro, Peel, York and Durham appear to be generally similar (with, for example, about 61 to 63% of shopping destinations having home as their origin, 10.4 to 13.7% having a previous shopping stop as their origin, with the remainder of the origins being other non-home locations, most notably work or personal business). Halton and Hamilton-Wentworth Regions, however, display a somewhat different breakdown, with an apparently higher degree of multi-stop shopping trip chains (as indicated by a lower percentage of home origins and a higher percentage of previous shopping stop origins relative to the other regions).

In order to obtain a crude feeling for the importance of trip chaining effects in explaining the poor goodness-of-fit of the shopping trip regressions considered previously, the region-specific equations were re-estimated using all shopping trips (home-based plus non-home-based) made by a given household as the dependent variable. Table 2.4 presents the results of this analysis, in which it is seen that the only effect of this change is to increase the magnitude of the equations' coefficients (reflecting the higher trip rates now being modelled). The goodness-of-fit measures for these equations are actually slightly lower than for the comparable home-based results (cf. Table 2.3), reflecting that the variability in the behaviour being modelled (i.e., shopping trip generation)

Table 2.3

Household Home-Based Shopping Regression Results
by Regional Municipality

AGGREGATE TRIP RATES

REGION	TOTAL TRIPS	TOTAL HOUSEHOLDS	TRIP RATE
Metro	7363	34385	0.214
Durham	1474	3999	0.369
York	1378	4246	0.325
Peel	2317	7149	0.324
Halton	1551	3659	0.424
Hamilton	2368	5799	0.408

REGRESSIONS

- Variables:
  - No. of Persons (NPERS)
  - No. of Vehicles (NVEH)
  - No. of Full-Time Workers (NFTW)
  - No. of Persons > 65 Years Old (NPER65)

REGION	INTERCEPT	NPERS	NVEH	NFTW	NPER65	R^2
Metro	0.075	0.047	0.069	-0.075	0.097	0.042
Durham	0.257	0.057	0.031	-0.109	0.167	0.034
York	0.246	0.047	0.036	-0.112	0.123	0.032
Peel	0.241	0.059	0.050	-0.134	0.115	0.038
Halton	0.256	0.083	0.045	-0.144	0.133	0.043
Hamilton	0.259	0.068	0.048	-0.144	0.206	0.060

All coefficients are statistically significant at a 95% confidence level or better.

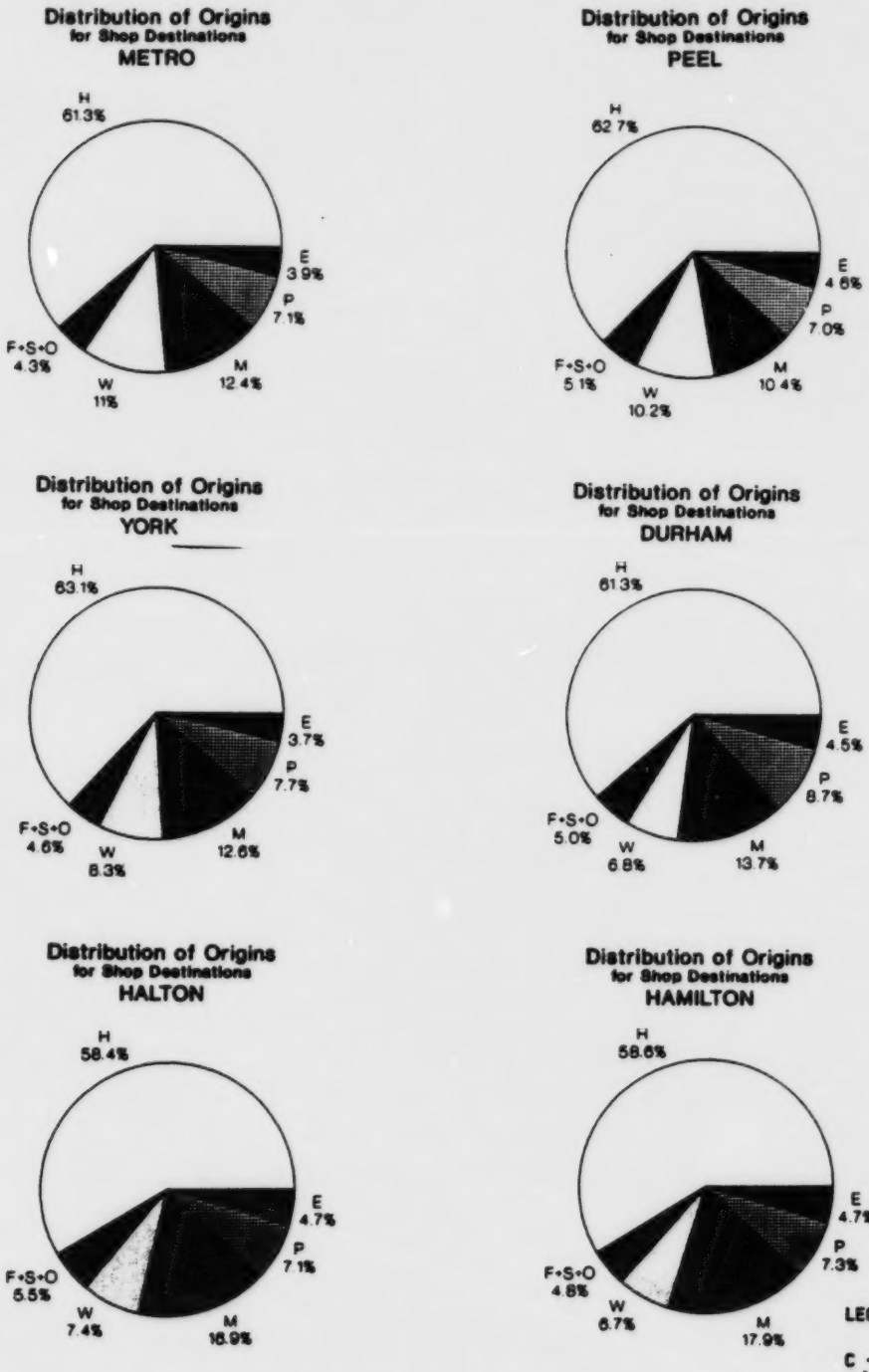

Figure 2.7

Distribution of Origin Stop Purposes for Shopping Stop Destinations by Regional Municipality

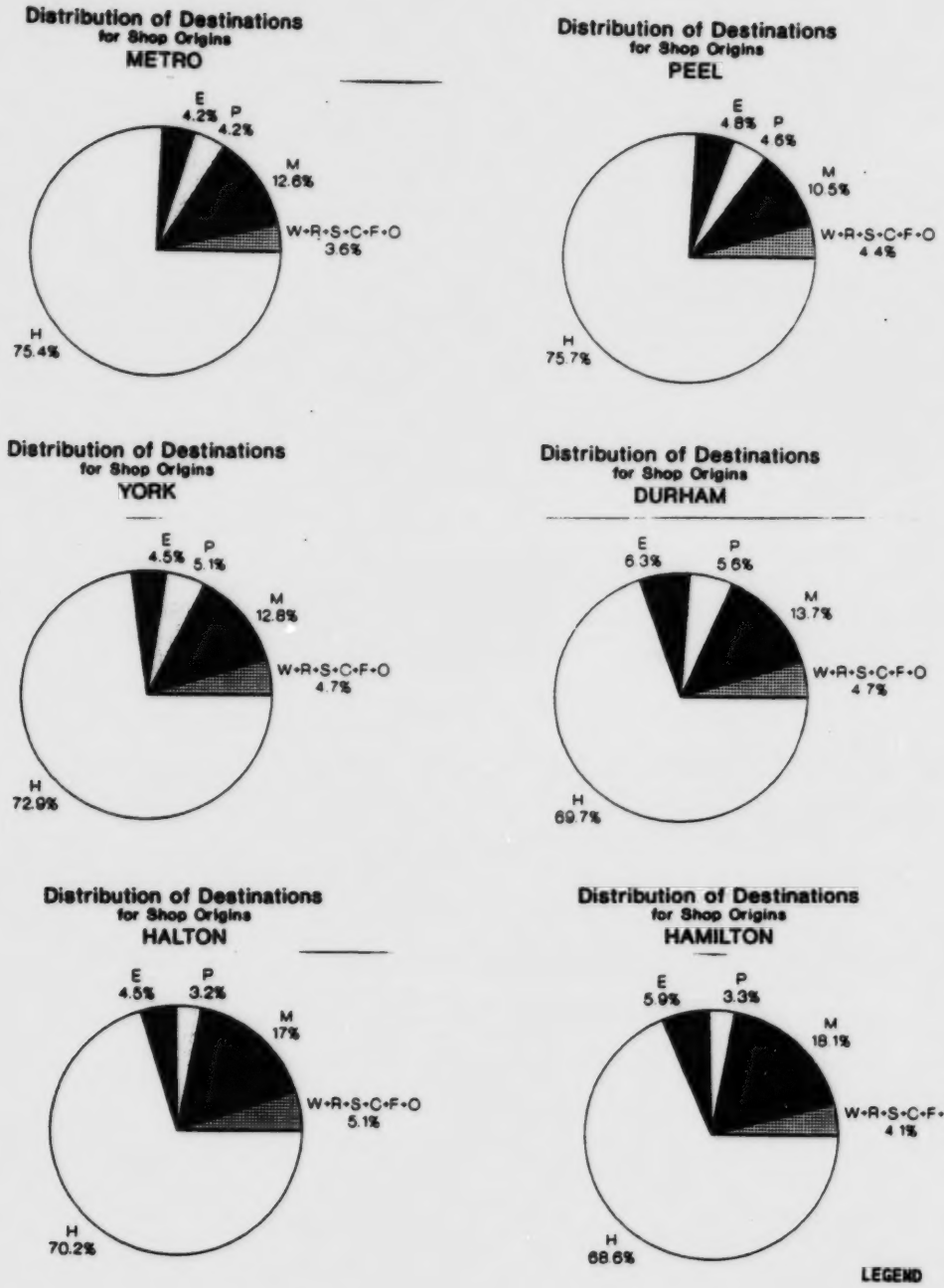

Figure 2.8

Distribution of Destination Stop Purposes for Shopping Stop Origins by Regional Municipality

Table 2.4

Household Shopping Trip Rates (HB + NHB)
Regression Results by Regional Municipality

AGGREGATE TRIP RATES

REGION	TOTAL TRIPS	TOTAL HOUSEHOLDS	TRIP RATE
Metro	12167	34385	0.354
Durham	2431	3999	0.608
York	2201	4246	0.518
Peel	3727	7149	0.521
Halton	2673	3659	0.731
Hamilton	4087	5799	0.705

REGRESSIONS

- Variables:
  - No. of Persons (NPERS)
  - No. of Vehicles (NVEH)
  - No. of Full-Time Workers (NFTW)
  - No. of Persons > 65 Years Old (NPER65)

REGION	INTERCEPT	NPERS	NVEH	NFTW	NPER65	R^2
Metro	0.155	0.058	0.121	-0.103	0.105	0.037
Durham	0.489	0.076	0.073	-0.198	0.124	0.026
York	0.443	0.062	0.062	-0.180	0.106	0.028
Peel	0.418	0.072	0.094	-0.200	0.122	0.037
Halton	0.554	0.121	0.079	-0.268	0.111	0.037
Hamilton	0.477	0.091	0.096	-0.202	0.243	0.036

All coefficients are statistically significant at a 95% confidence level or better.

has been increased, without a commensurate increase in the independent variables' ability to explain this variability.[8] Thus, it must be concluded that linear regression models are not adequate to explain household-level shopping trip generation behaviour.

2.4 Person-Based Trip Generation Rates

An alternative disaggregate unit of analysis to that of the household is the individual person. Advantages of the use of the individual as the unit of trip generation analysis include: trips are, ultimately, made by individuals, generally to accomplish individual objectives (e.g., travel to work or school), socio-economic information is often recorded with respect to people rather than households, and often the most straightforward means of aggregating to zonal totals is on the basis of persons, rather than households.

Rather than adopt a formal statistical analysis of person-based trip rates comparable to that performed for the household-based trip rates discussed in the previous section,[9] it was felt that a more useful approach for the purposes of this study would be to directly plot person-based trip generation rates by purpose and mode as a function of person characteristics, notably the person's age and sex. Figures 2.9 through 2.11 provide representative plots of these trip rates for Metro and one non-Metro region for auto work trips, transit work trips and auto non-work trips. In all cases, trip rates for men, women and both sexes are shown as a function of the person's age, where age has been aggregated into five year intervals (0-5, 6-10, 11-15, etc.). Also in all cases, the trips indicated represent one-way home to destination purpose (i.e, work or non-work) trips. Finally note that no attempt has been made to control for the number of persons in a given age-gender cell, with the result that a few of the plotted points (principally most of the points for people over 65 years of age) can have limited reliability. Appendix A presents the entire set of these plots for all six regional municipalities.

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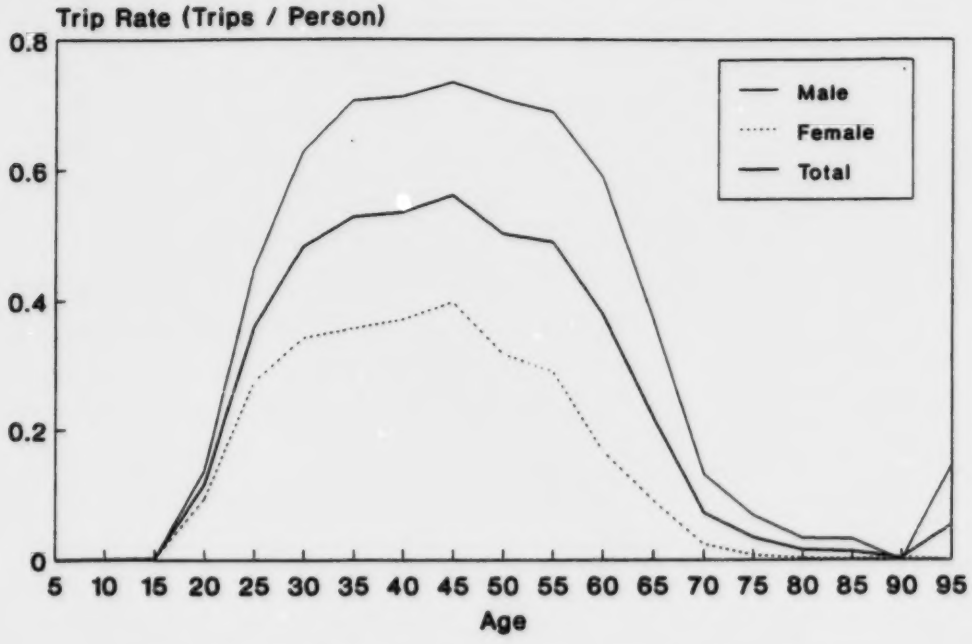
[8] Part of this increased variability may be due to the non-reporting bias known to exist in the dataset for non-work, non-home-based trips.

[9] For example, a linear regression analysis of person trip rates as a function of personal and household characteristics, or, virtually equivalently, an analysis of variance investigation of these relationships. For a good example of this latter type of analysis applied to recent trip data for the Regions of Niagara, Waterloo and London, see Tranplan Associates [1990]. This type of analysis was not undertaken within this study due to time limitations and due to lack of readily available software capable of performing an analysis of variance on the large TTS dataset.

Auto Trip Rates by Age for Work Trips
for METRO Region



Auto Trip Rates by Age for Work Trips
for DURHAM Region

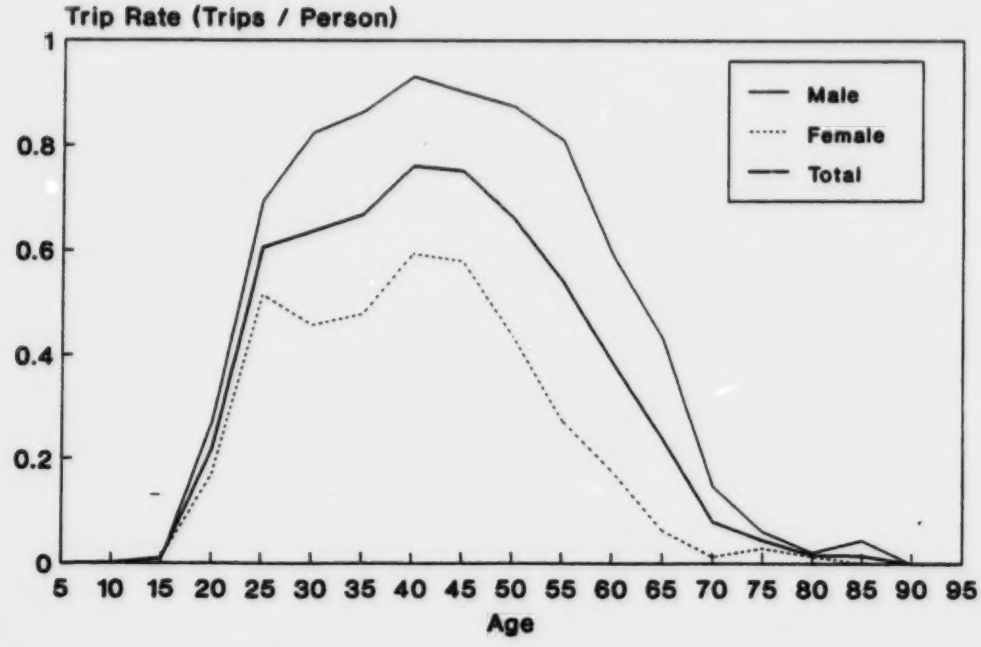
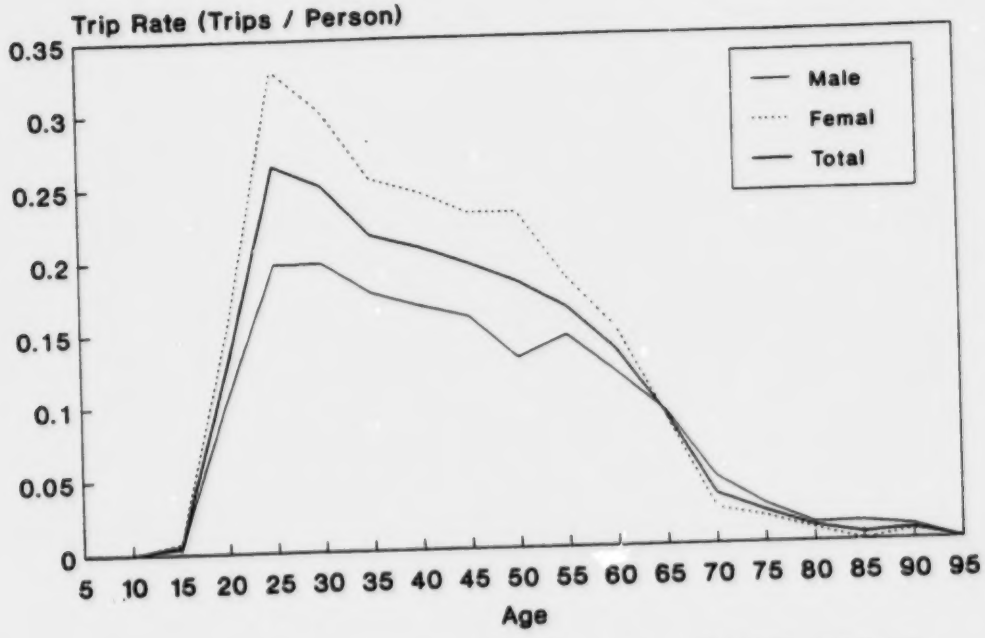


Figure 2.9

Person Home-to-Work Auto Trip Rates by Age and Sex, Metro and Durham Regions

Transit Trip Rates by Age for Work Trips
for METRO Region



Transit Trip Rates by Age for Work Trips
for HALTON Region

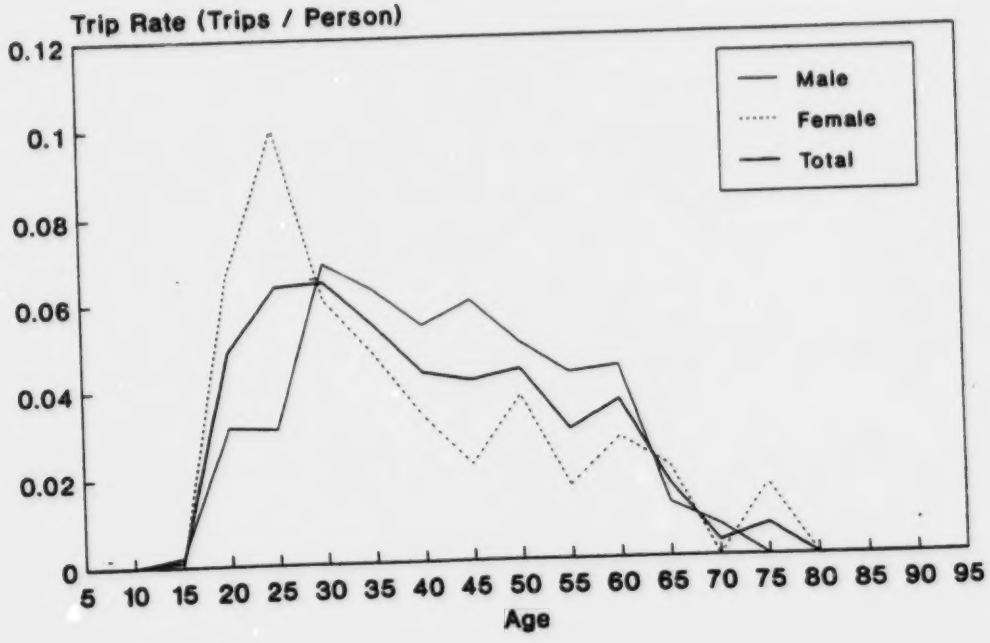
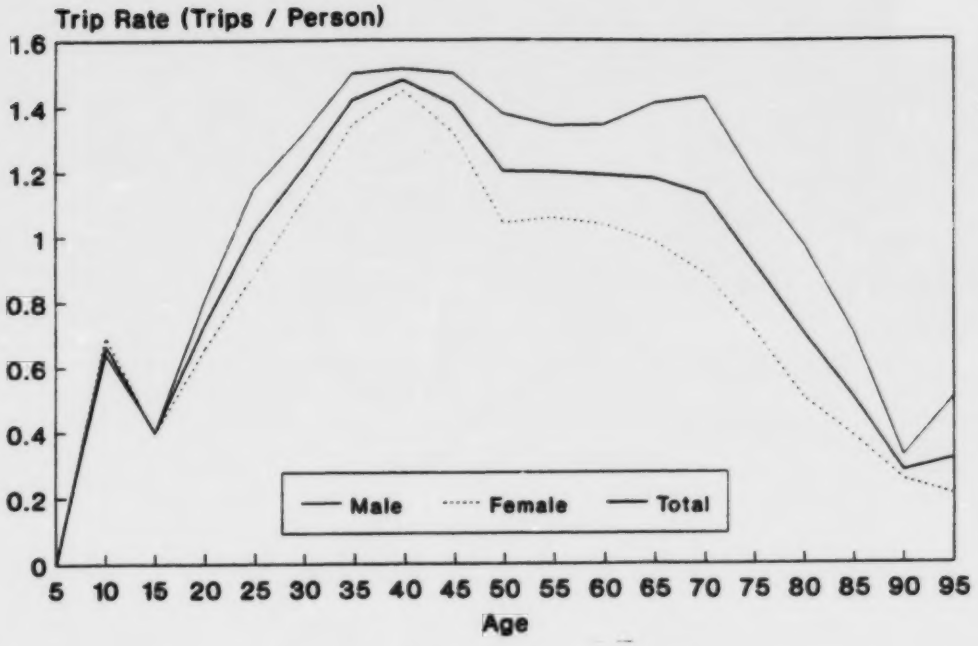


Figure 2.10

Person Home-to-Work Transit Trip Rates by Age and Sex,
Metro and Halton Regions



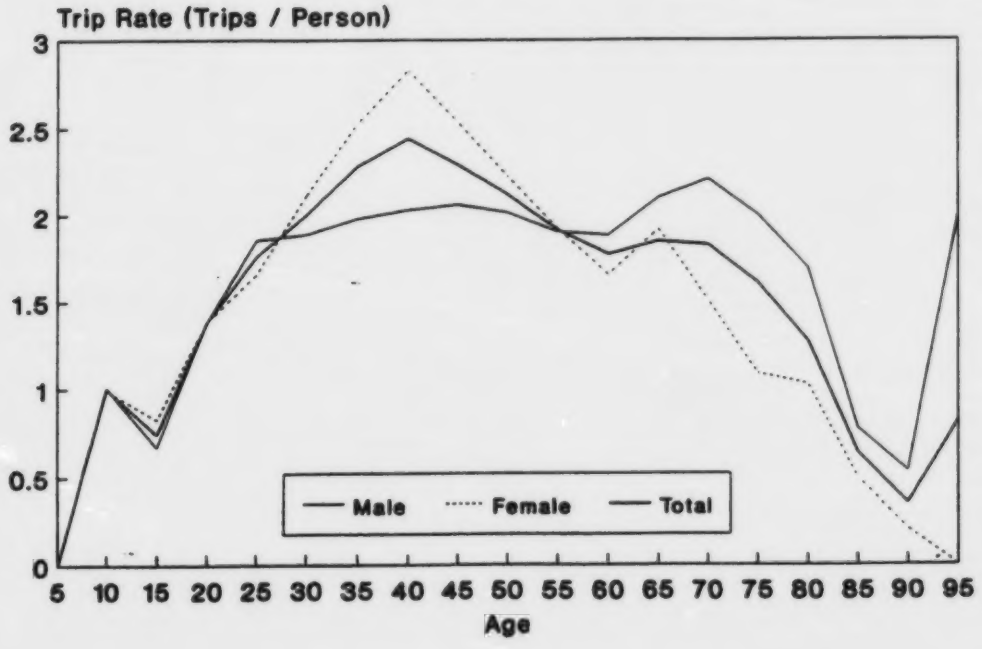


Figure 2.11

Person Home-to-Non-Work Auto Trip Rates by Age and Sex, Metro and Halton Regions

While the inter-regional differences in trip generation behaviour displayed in Figures 2.9 - 2.11 (and, in more detail, in Appendix A) are intuitively plausible, one must question whether such a large physical area as a regional municipality, with its typically diverse distribution of land uses (ranging, particularly outside of Metro, from rural to relatively dense urban), is an appropriate basis for aggregating people together. In particular, it is reasonable to expect that, as a region's nature and distribution of land use, or its "level of urbanization", changes over time, the trip-making propensities of its inhabitants might change as well. This, in turn, raises the question of whether a more appropriate spatial classification of people might be found that allows more fundamentally sound trip generation relationships to be developed.

The approach adopted in this study in an attempt to achieve this more "fundamental" spatial aggregation is to establish a measure of "urban density", which is loosely defined as a measure of the extent to which a given zone is "urban" in nature (as opposed to "suburban" or "rural"), and hence the extent to which people living within this zone exhibit "urban" versus "suburban" or "rural" trip-making behaviour. If such a classification of zones (and hence of the population living within these zones) could be achieved, then it is hypothesized that, as these zones evolve over time in terms of their urban density, the trip-making behaviour of the residents of these zones will evolve in a commensurate fashion. The issue of the use of urban density as a variable to forecast future trip-making (as well as the associated issue of forecasting future urban densities) is addressed in Volume III of this report series [Miller, et al., 1990]. The concern of this present discussion is to establish a working definition of "urban density" and to determine whether discernable and explainable differences in trip generation rates exist within different density levels.

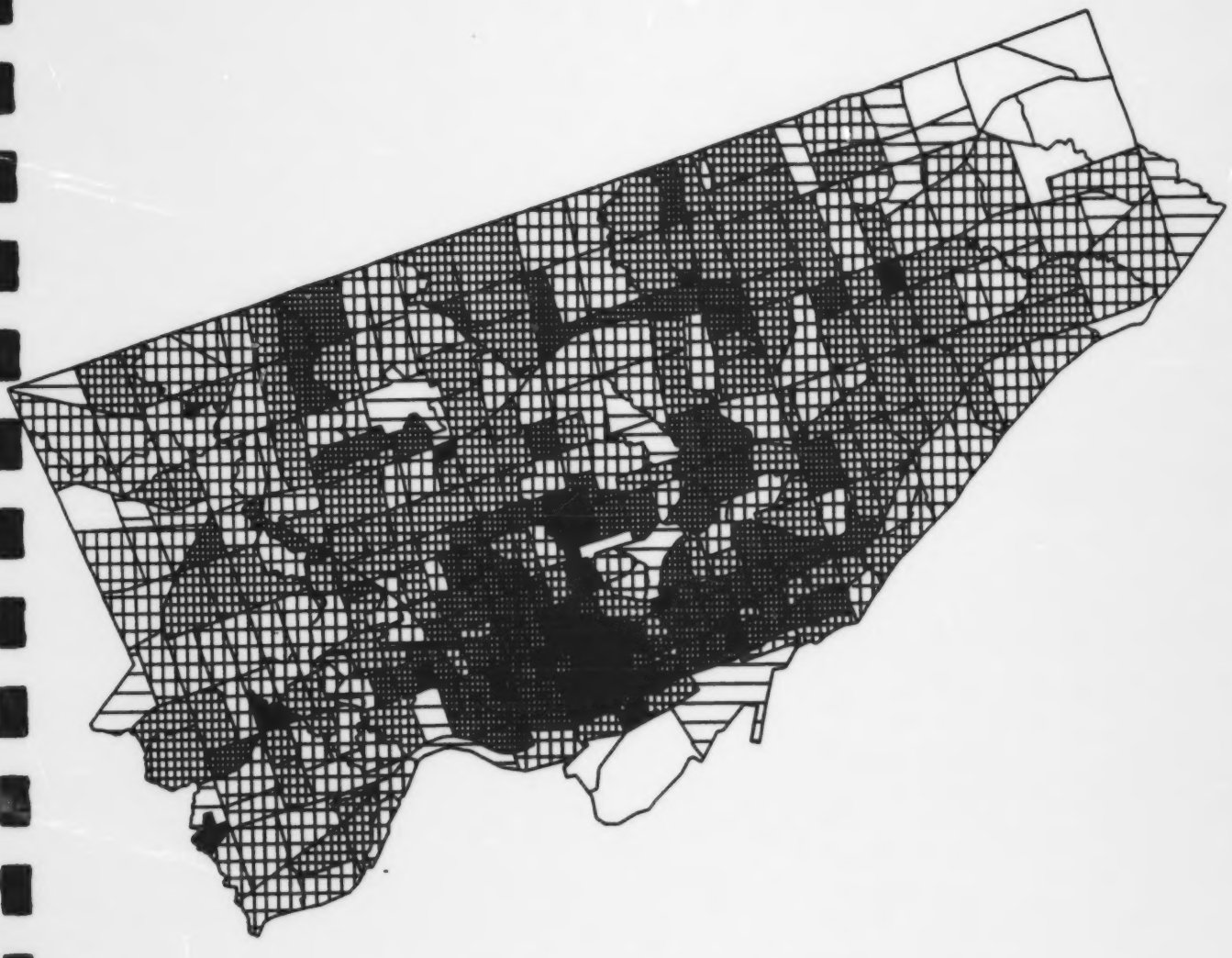
Three simple measures of the urban density of a given zone were examined in this study: the zone's density of resident population, the zone's density of employment, and the zone's density of trip ends (productions plus attractions, for all purposes). In all three cases, the density was computed on a per unit area basis and 1979 TARMS zones were used as the basic spatial unit. Of the three, the trip-end density measure appeared to be by far the "best", in that it generated an intuitively sensible spatial distribution of urban density that corresponds well to the density of building stock and activity levels throughout the GTA.[10] In particular, if one somewhat arbitrarily defines the "density class" categories defined in Table 2.5, then Figures 2.12 - 2.14 display the

[10] A density measure based on actual building stock might be a preferred (and somewhat more "objective") measure. Such a measure was simply impossible to construct within the constraints of this study.

Table 2.5

Trip-End Density Class Definitions

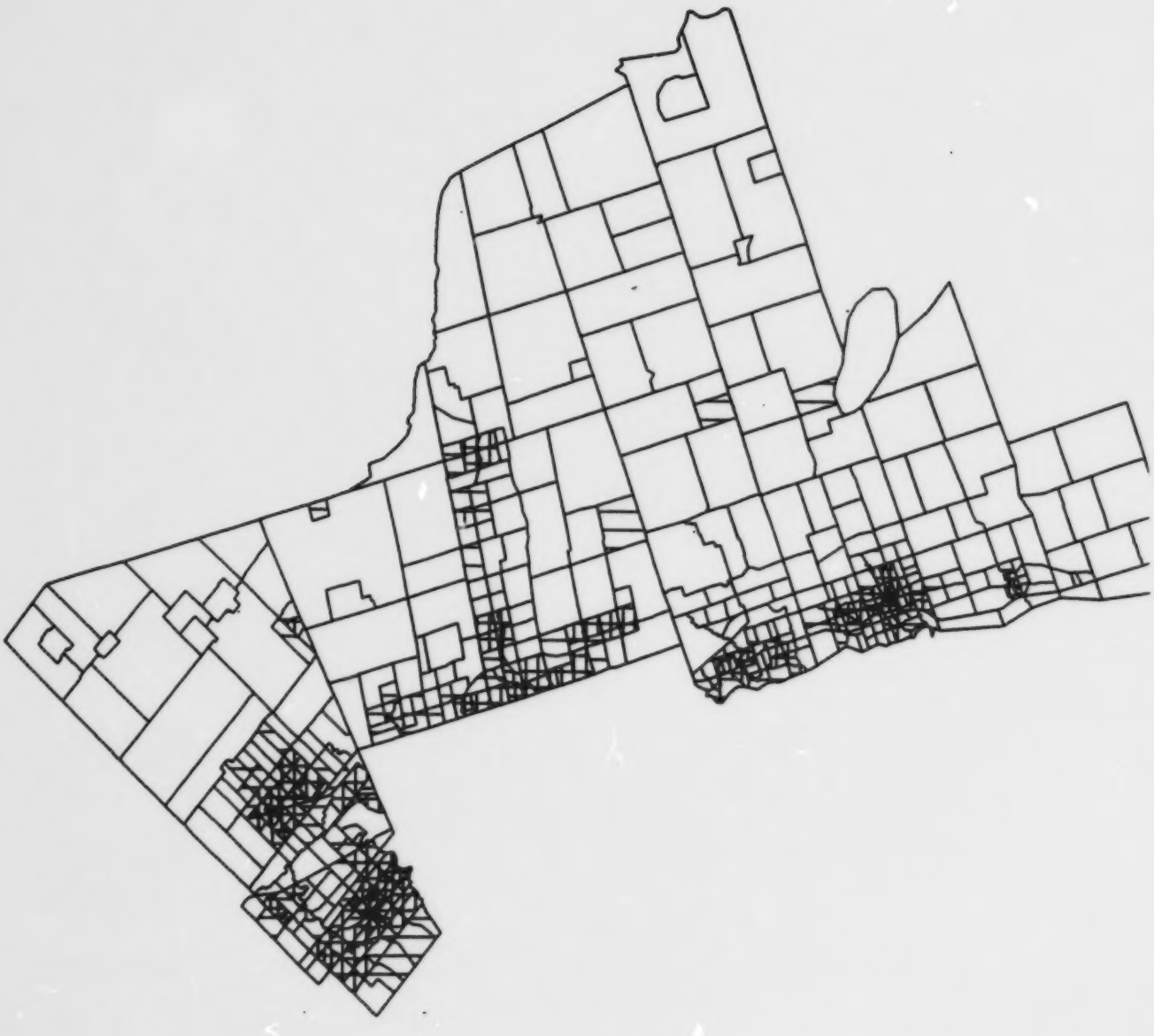
DENSITY CLASS NO.	PERCENTILE RANGE	TARMS ZONE RANK NOS.
1	0 - 30	1 - 354
2	>30 - 45	355 - 531
3	>45 - 70	532 - 826
4	>70 - 85	827 - 1003
5	>85 - 95	1004 - 1121
6	>95 - 100	1122 - 1180



Density Class	Trip Ends per km²
1	< 927
2	928 to 4794
3	4795 to 11548
4	11549 to 18467
5	18468 to 35924
6	> 35924

Figure 2.12

1986 Trip-End Density Distribution, Metro Toronto



Density Class	Trip Ends per km²	Density Class	Trip Ends per km²	Density Class	Trip Ends per km²
1	< 927	2	928 to 4794	3	4795 to 11548
4	11549 to 18467	5	18468 to 35924	6	> 35924

Figure 2.13

1986 Trip-End Density Distribution, Durham, York and Peel Regions

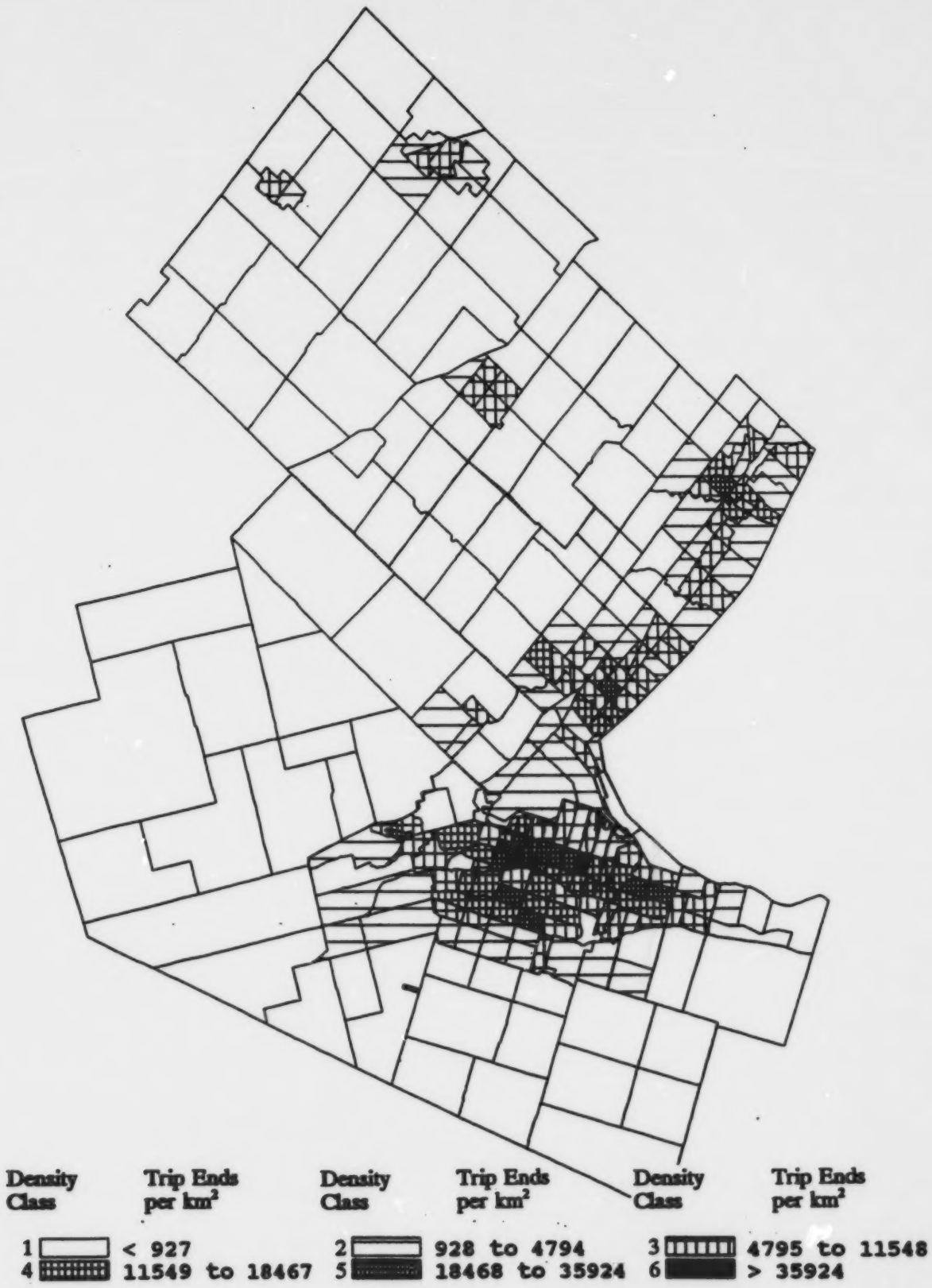


Figure 2.14

1986 Trip-End Density Distribution, Halton and Hamilton-Wentworth Regions

1986 distribution of urban density for the GTA; a distribution which conforms quite well with _a priori_ notions of how "urban density" should vary over the GTA. Further, given that trip-ends generally correlate well with population and employment, the trip-end density measure combines elements of both of the other two measures.[11]

Age-gender distributions of trip generation rates by purpose and mode were recalculated for people living in each of the six density classes. A complete set of these distributions is provided in Appendix B, while Figures 2.15 - 2.17 provide representative examples for Metro and non-Metro regions. Points to note from these figures include:

1. The high density class 6 auto work trip rates are much lower than the auto work tip rates for the "rural", low density class 1 (Figure 2.15). This is largely due to the much higher use of transit by these workers (cf. Figure 2.16). It may also reflect a somewhat lower labour force participation rate within high density areas.

2. Women in low density (class 1) regions generally have a much lower work trip rate than men in either density class or women in the high density zones (class 6). They also exhibit a distinct drop in work trip rates during the primary child-bearing years (late twenties, early thirties), with this trip rate increasing again in the forties, presumably as their children grow older. This drop does not really occur in the density class 6 case.

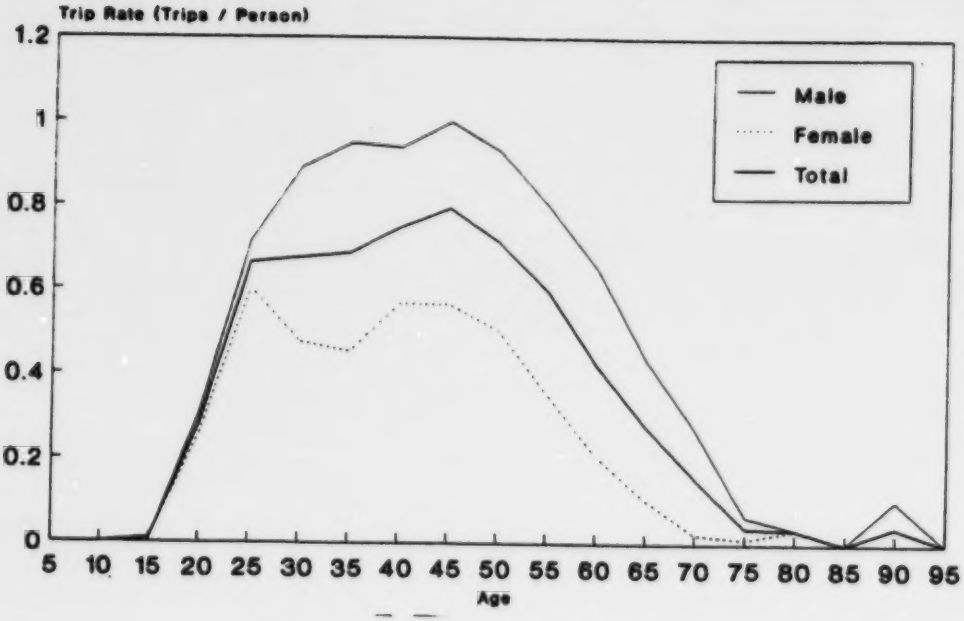
3. Transit is a very minor mode for work trips from density class 1 zones, whereas a significant proportion of density class 6 work trips use transit. This obviously reflects the relative availability and level of service provided by the transit system to commuters in these two areas.

4. As indicated by the previous three points, work trip rates by age, sex and mode generally depend upon a large number of factors, including labour force participation rate, modal choice opportunities, and the extent to which workers work at home or do not have a fixed workplace. It therefore seems reasonable that if one is interested in controlling for the effect of factors such as demographic characteristics (age, gender) and modal opportunities on work trip rates, one should model labour force participation as a function of age, sex and location (density class) and then model work trip generation as a function of the number of full-time and part-time workers resulting from this labour force participation.

5. Non-work auto trip rates are relatively constant over a wide age range for both density classes 1 and 6, with the major difference between the two density classes being the markedly lower average trip rate for the high density zones. As discussed in the previous section, this reflects the absence of walk trips for non-work purposes, which will tend to bias downwards the number of non-work trips reported in dense

[11] For a more detailed discussion of the development and testing of this measure of urban density, see Jea [1990].

Trip Rates for Density Class 1
Auto Mode, 24 Hours
for Work Trips



Trip Rates for Density Class 6
Auto Mode, 24 Hours
for Work Trips

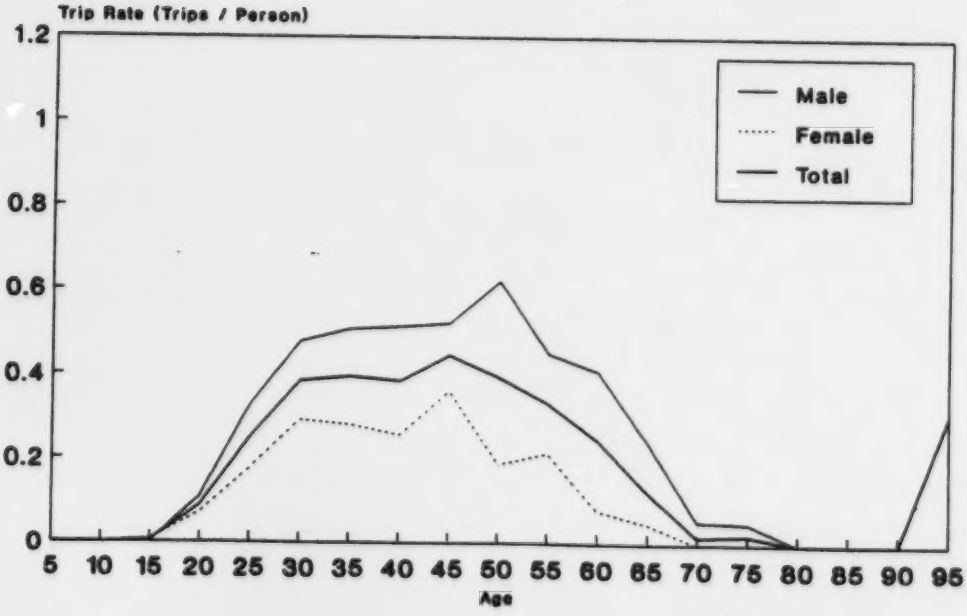
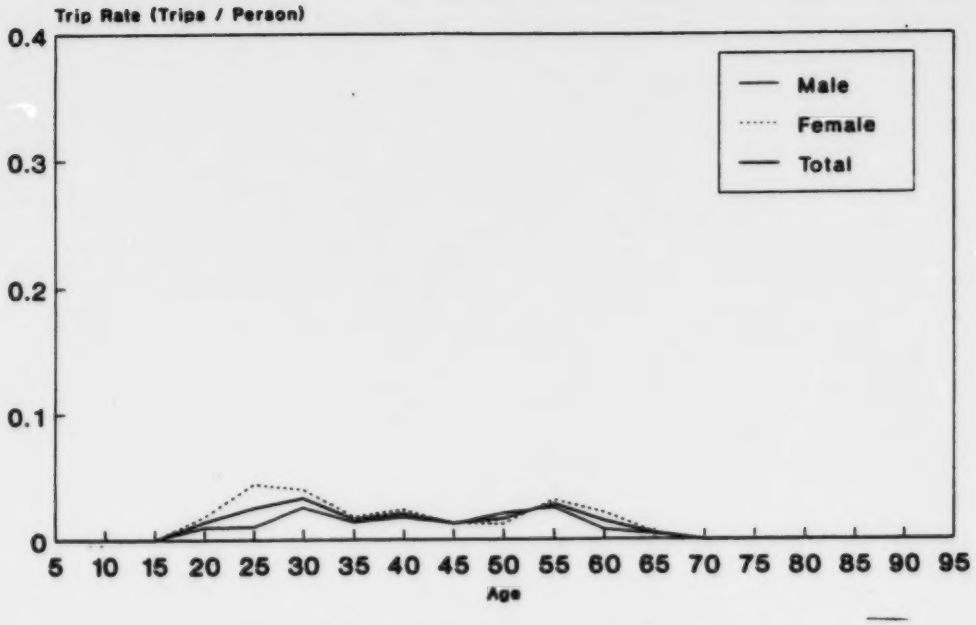


Figure 2.15

Person Home-to-Work Auto Trip Rates by Age and Sex, Density Classes 1 and 6

Trip Rates for Density Class 1
Transit Mode, 24 Hours
for Work Trips



Trip Rates for Density Class 6
Transit Mode, 24 Hours
for Work Trips

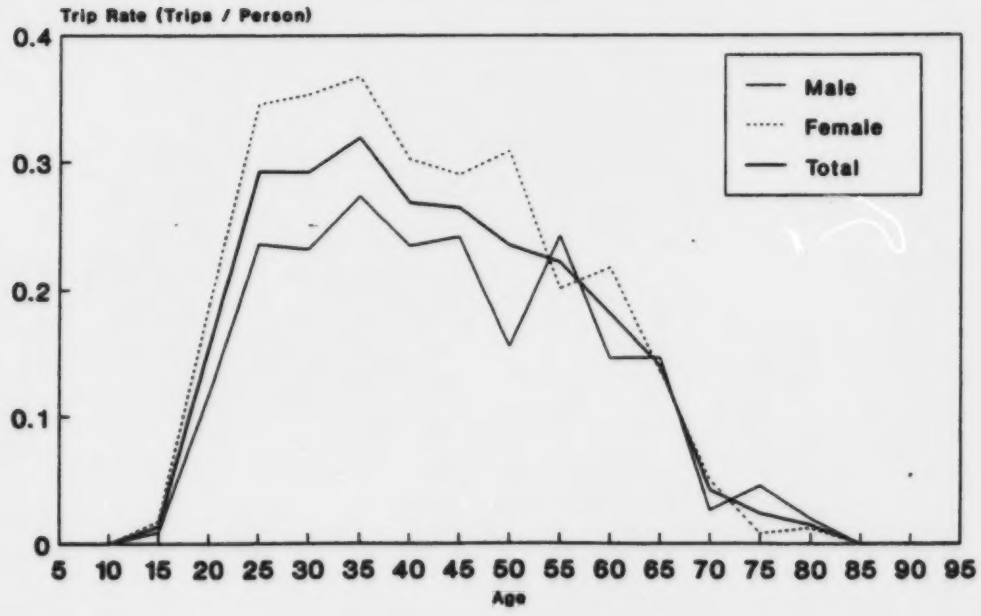
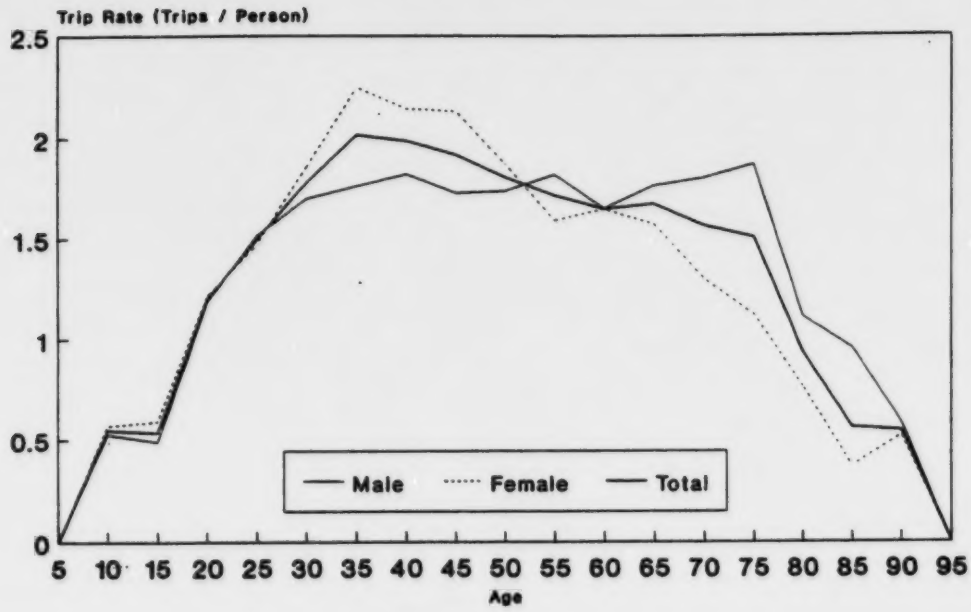


Figure 2.16

Person Home-to-Work Transit Trip Rates by Age and Sex, Density Classes 1 and 6



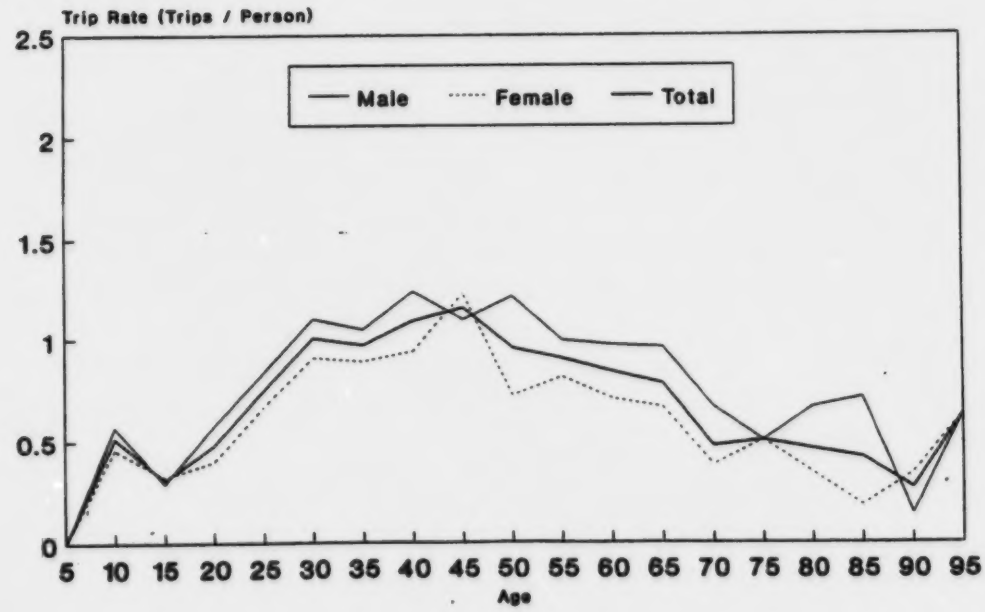


Figure 2.17

Person Home-to-Non-Work Auto Trip Rates by Age and Sex, Density Classes 1 and 6

areas, as well as a higher transit usage among these travellers.

6. The male-female differences in non-work auto trip rates are generally less than in the work trip case. The one exception is the peak in density class 1 female non-work trip rates in the 30 to 45 age groups. Further examination of these trip-rates by more detailed breakdown of trip purpose indicates that a significant proportion of these trips are for the "serve passenger" purpose, which is again consistent with the assumption that many women in these age groups in this density class are at home with children.

An alternative to the trip-end density measure that was briefly investigated was the construction of a simple "accessibility" measure of the form:

$$[4] \qquad A_{ip} = \sum_{j} X_{jp} d_{ij}^{-2}$$

where:

A_{ip} = accessibility of zone i for trip purpose p (work, etc.)

X_{jp} = measure of activity level for purpose p at destination zone j (e.g., employment level in zone j)

d_{ij} = straight-line centroid-to-centroid distance between zones i and j

Although even in this very crude form a more complicated measure to compute than trip-end density, it was felt that accessibility might prove to be a more useful explanatory variable than trip-end density, since it provides a measure of a given zone i's location relative to its surroundings, in particular relative to the opportunities for trip-making activities.

Three accessibility measures were examined, based on employment, resident population, and trip-ends as the "X" variable. In each case, spatial distributions of accessibility generally similar in nature to the density distributions of Figures 2.12 - 2.14 were obtained. Thus, the simple accessibility measures tested provided little new information about spatial structure relative to the simpler density measure. Given a lack of time to develop more appropriate (and, possibly, more powerful) accessibility measures, this line of inquiry was dropped in favour of the use of the trip-end density measure for the purposes of this study. It is felt, however, that the concept of accessibility is a potentially powerful one, and one that is deserving of further study in the future.

2.5 Zonal Trip Generation Rates

Although household-based or person-based trip generation relationships are more defensible on a behavioural basis, zone-based relationships are often employed in practice due to their simplicity and their reduced data requirements, particularly for forecasting purposes. Several simple regression equations were estimated, in which the dependent variable is the number of 24-hour trips for a given purpose originating from or destinated to a given TARMS zone, both in order to explore the nature of zonal trip generation relationships and to provide a basis for some of the forecasting work described in Volume III.

Table 2.6 provides a set of zonal regression equations. The first two equations (numbers [5] and [6]) simply represent a spatially aggregate version of equation [1], but with an additional disaggregation by worker gender. Comparing these results with equation [1] indicates that little bias is likely to have been introduced through the spatial aggregation in this case. The third equation (number [7]) estimates home-to-work destinations, with destination zone total employment as its sole explanatory variable, since this is the only destination-specific variable available for both 1986 and the forecast years of 2001 and 2011 employed in the Volume III analysis. The final equation in the table (number [8]) simply estimates work to "other" trip generations by work zone as a function of the zone's employment level. The equations in Table 2.6 were developed primarily for the Volume III forecasting exercise and are discussed further there.

Table 2.6

Zonal Regression Equations

[5] $TRIPS_{male} = -4.103 + 0.779*FTW_{male} + 0.345*PTW_{male}$ $(R^2 = 0.988)$

[6] $TRIPS_{fem} = -6.126 + 0.801*FTW_{fem} + 0.387*PTW_{fem}$ $(R^2 = 0.987)$

$TRIPS_i$ = No. of 24-hour home-based work trip chains "produced" in home-zone, for sex i

FTW_i = No. of full-time workers, sex i, in home zone

PTW_i = No. of part-time workers, sex i, in home zone

[7] $TRIPS_a = -10.334 + 0.715*EMP$ $(R^2 = 0.878)$

$TRIPS_a$ = No. of 24-hour home-based work trip chains "attracted" by the work zone

EMP = No. of jobs in the work zone

[8] $TRIPS_{wb} = 6.117 + 0.0391*EMP$ $(R^2 = 0.785)$

$TRIPS_{wb}$ = No. of 24-hour "other purpose", work-based trip chains generated in the work zone

EMP = No. of jobs in the work zone

All coefficients for the explanatory variables are statistically significant at a 95% confidence level or better, as are the intercept terms for equations [6] and [8]. The intercept terms for equations [5] and [7] are not significantly different from zero at standard levels of confidence.

CHAPTER 3

REVIEW OF TRIP GENERATION RATES IN OTHER URBAN AREA

3.1 Introduction

The primary focus of this research project involves the analysis of current trip generation relationships within the GTA. Nevertheless, a brief review of the literature pertaining to trip generation, both within Canada and elsewhere is useful to provide a context and an comparison to the GTA findings. This chapter provides such a brief review. It is divided into two sections. Section 3.2 deals with recent findings from three other major Canadian cities, all of whom have travel behaviour databases at least comparable to the GTA: Montreal, Ottawa, and Vancouver. Section 3.3 then presents a review of a somewhat more eclectic collection of papers and reports dealing with trip generation relationships and modelling results obtained from the United States and elsewhere.

3.2 Recent Findings in Montreal, Ottawa and Vancouver

Vancouver and Ottawa tend to be in similar positions to Toronto with respect to transportation demand modelling in that both also have undertaken recent major travel behaviour surveys and both are actively investigating trip-making relationships and rebuilding their travel demand forecasting models on the basis of these survey data.

The TRANS Committee of the greater Ottawa area has recently completed a major trip generation study designed to update their trip generation modelling capabilities.[Delcan, 1989a, 1989b] The result is a very interesting and comprehensive trip generation database and modelling system for the Ottawa region. Unfortunately from the point of view of this project, however, the entire TRANS analysis of trip generation rates is based on computing vehicle trips as a function of land-use (i.e., vehicle trips per unit area of floorspace by land-use type, or vehicle trips per residential dwelling unit by type), similar to the approach which has been standardized with the ITE Trip Generation Handbook.[ITE, 1987] Thus, it is very dificult to compare Ottawa trip generation rates with those found in this report for the GTA, which are expressed in terms of person trips on a per household or per person basis.

Barnard and Brindle [1987] lable the TRANS/ITE approach "traffic generation" since it defines generation on a vehicle-trip basis, as opposed to "trip generation" which is expressed on a

person-trip basis. As they observe, the two concepts are clearly inter-related and should ultimately yield consistent results. For the purposes of this study, however, a person-trip representation of travel would appear to be the more fundamental of the two approaches, since the vehicle-trip representation subsumes within it questions of modal choice and vehicle occupancy -- questions which are beyond the scope and interest of the current research. For further discussion of issues associated with "traffic" generation methods, however, see Barnard and Brindle [1987].

The Development Services branch of the Greater Vancouver Regional District (GVRD) has also recently developed a trip generation model for greater Vancouver, based on the Metropolitan Origin and Destination Survey conducted in the Vancouver region in 1985. While this model does compute trip generation as a function of population and employment levels (as in this study), it does so on the basis of peak-hour trip rates for zonal productions and attractions (in the conventional sense of these terms). Thus, these trip rates are again difficult to compare directly with the rates developed in this study, which are twenty-four rates for trip origins and destinations. It is of interest to note, however, that the GVRD model identifies four trip purposes to be modelled: work trips, post-secondary school trips, grade school trips, and "leisure/family/shop/personal business/home" (L/F/S/PB/H) trips. In all cases, trip productions and attractions are computed on a zonal basis using linear regression equations. Table 3.1 summarizes the explanatory variables used in the eight equations (productions and attractions for four purposes).

Montreal is in a far different position with respect to its travel demand database than Toronto, Ottawa or Vancouver (or, indeed, most other North American cities), in that major travel surveys have been conducted approximately every four years within Montreal since 1970. Montreal thus is blessed with relatively consistent time series information of trip-making activity over a twenty year period. This enables analysts to examine trends in travel behaviour and to relate changes in travel behaviour to changes in the demographic and economic factors affecting travel demand, in a way which is simply impossible in most other cities due to the cross-sectional, "one-shot" nature of the databases which typically exist in these cities. The existence of such a rich database has not gone unnoticed by transportation analysts, who have collectively exploited it as a basis for a wide range of research studies.

Perhaps the best known user of this database is Robert Chapleau, who, along with his colleagues at the Ecole Polytechnique, University of Montreal, has extensively analyzed trip-making

Table 3.1

Explanatory Variables Used in the GVRD
Trip Generation Model

Trip Purpose	Explanatory Variables[1] Trip Productions	Trip Attractions
Work	Resident Labour Force Retail Floorspace Employment Grade School Destinations[2]	Employment
Post-Secondary School	Population, Age 18-24	Post-Secondary Destinations[2]
L/F/S/PB/H	Employment Retail Floorspace Residential Non-Labour Force[3] Grade School Destinations[2]	Retail Floorspace Residential Non-Labour Force[3]
Grade School	Population, Age 5-17	Grade School Destinations[2]

Notes:

1. All variables expressed as zonal totals.
2. Observed 1985 trip ends from the O/D survey are currently used. School enrollments may be used in the future.
3. Residential Non-Labour Force = (Population) - (Resident Labour Force).

trends in Montreal, principally with respect to transit usage. Typical of this work is the 1986 paper by Chapleau and Girard, which uses data from the 1970, 1974, 1978 and 1982 surveys to explore the effects of population aging and urban structure on future transit use within Montreal. Findings of this study include:

1. male labour force participation rates declined during the analysis period, while female labour force participation rates in the 25-44 year age group increased;

2. overall, work trips declined as a percentage of total trip-making;

3. male and female workers exhibit different transit usage rates, whereas male and female students do not;

4. car ownership and auto mode splits increased during the study period; and

5. the impact of population aging, changes in labour force participation rates, etc. on trip rates over time were examined, both in terms of simply tabulating the observed rates over time, as well as developing a simple time-series model to project future transit ridership as an extrapolation of the past trends.

A second major user of the Montreal database is Yves Bussiere at the National Institute of Scientific Research, University of Quebec, who, similar to Chapleau, has investigated the implications of demographic changes for travel demand by mode within the Montreal region. Initially using 1978 modal trip rates by age and sex, he projected future travel demand by mode based on projected population age-sex profiles.[Bussiere, 1984] Later, he extended the analysis using 1982 data as well.[Bussiere, et al., 1987] Table 3.2 summarizes the basic point of the research, in which it is seen that both younger and older people tend to have higher transit mode splits (Table 3.2b), but older people have lower total trip rates (Table 3.2a). Hence, as the population tends to age, the transit trips lost due to lower numbers in the younger age groups are not compensated for by the increased number of elderly people. The net result is shown in Table 3.2c, in which it is seen that if one were to ignore the effect of shifting population demographics, then one is likely to significantly underestimate future auto usage and, at the same time, significantly overestimate future transit usage.

The specifics of the Montreal experience, useful as they are due to their time-series nature, must be carefully interpreted if they are to be transferred to other urban areas. In particular, the demographic and economic trends in Montreal during the 1970's and much of the 1980's were different in many ways from those which occurred in Toronto. Nevertheless, the observation that

Table 3.2
Implications of Considering Demographic Effects on Future Travel Demand, Montreal, 1978-1991 Source: Bussiere [1984]

(a) An estimate of the average number of per capita daily directional trips, by age group in the Montreal Metropolitan Region, 1978

Age group	Average number of trips per capita
5-11	0.92
12-16	1.11
17-19	1.01
20-24	1.18
25-54	1.11
55-64	0.69
65 and over	0.49
Total 5 and over	0.996

(b) Percentage distribution of transportation mode used by age group, Montreal Metropolitan Region, 1978

Age group	Type of user	Mode of transportation chosen (%)						
		Walking	School bus	Public transp.	Automobile driver	Automobile passenger	Taxi	Total
5-11	Children of kindergarten and primary school	43.2	37.9	6.4		12.5		100
12-16	Children of secondary school	28.9	33.4	27.9	0.3	9.2	0.3	100
17-19	High school students	10.0	3.3	48.3	17.2	21.1		100
20-24	University students and young workers	9.4		34.6	35.5	19.9	0.6	100
25-54	Workers of both sexes and housewives	6.3		21.1	57.8	14.0	0.8	100
55-64	Same as the immediate above and preretired	12.5		25.0	46.7	14.7	1.1	100
65 and over	Retired	26.2		41.3	19.8	11.1	1.6	100
Total 5 years and over		14.2	7.5	24.9	38.3	14.4	0.6	100

(c) Comparison of the variation in transportation demand by mode in the Montreal Metropolitan Region, 1981-1991, calculated as a whole and by age group

Method of calculation	Variation 1981-1991					
	Absolute numbers			Percent		
	Automobile driver	Automobile passenger	Public transport	Automobile driver	Automobile passenger	Public transport
Calculated by age group	+97,919	+12,156	+9,155	+9.4	+3.3	+1.4
Calculated without age effect	+72,297	+26,556	+45,383	+6.95	+6.95	+6.95
Difference	+25,622	-14,040	-36,228	+2.5	-3.7	-5.6

changing demographics and urban structures must be taken into account when projecting future travel demand would appear to be of universal applicability (with only the detailed nature of these changes and their impacts differing from one location to another), and it is precisely this observation which motivates much of the modelling effort described in Volume III of this report series.

3.3 Other Recent Findings in the Literature

In this section a selection of papers are briefly reviewed that deal with trip generation modelling results, principally from the United States, but also from Great Britain and the Netherlands. Emphasis is placed on the role of demographic and other variables in explaining trip generation, as well as on the dynamics of these relationships, but methodological issues are also briefly mentioned where relevant.

Kostyniuk & Kitamura [1987]: Although explicitly concerned with investigating likely future auto usage by the elderly using "level of motorization" (i.e., various combinations of possession of driver's licence and access to a car) as their measure of usage rather than trip generation per se, this paper is of direct relevance to this study in that it examines changes in travel behaviour over time as a function of changing demographics. In particular, the paper identifies three major types of effects on travel behaviour:

1. age effects, in which people in the same age category exhibit the same behaviour over time (i.e., the people in the age category change over time, but the within-category behaviour does not change);

2. cohort effects, in which people belonging to a given age cohort[1] may exhibit behaviour which is different from other cohorts, both in the cross-section and over time, where these effects are due to the unique experience of the given cohort relative to other cohorts; and

3. time effects, in which all people at a particular point in time are affected in a similar way (e.g., everyone who lived through the gasoline shortages of the 1970's might display some similar response to this stimulus).

Kostyniuk and Kitamura are particularly interested in the possible existence of cohort effects, because if these exist a dynamic model of travel behaviour is clearly required, since this

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[1] A cohort is here defined to consist of all people with the same year of birth. Hence, members of a cohort age and move through their lifecycles together.

behaviour will change over time as the particular cohorts move through time (i.e., the future elderly population will behave differently than today's elderly because they will be from different cohorts, will have experienced a different set of circumstances and will, consequently possess different behavioural patterns). In particular, Kostyniuk and Kitamura hypothesize that the extensive "motorization" of the current adult American population (i.e., exposure to and dependency on the automobile) will lead to travel patterns among future elderly which will be much more auto-oriented than the patterns exhibited by the current elderly population, whose "formative" years were pre-World War II -- a time which was far less auto-oriented than the post-War period.

Using data from travel surveys in 1963 and 1974 conducted in Rochester, N.Y., the authors performed simple cohort analyses to explore some of these hypotheses. In general, they found support for the hypothesis of a cohort effect at work in this population (i.e., trip-makers in Rochester) in that the effects of aging on mobility were found to vary across cohorts, and in that a model based on age effects alone was unable to replicate the observed changes in mobility with any reasonable level of statistical confidence. In other words, the distribution of mobility within Rochester as a function of age changed between 1963 and 1974. Based on this tentative conclusion, they suggest that the result may well extend to actual travel demand (e.g., trip generation, mode choice, etc.) as well, in which case, as noted above, a dynamic model of travel demand would be required.

Kitamura [1988]: In this study, Kitamura used Dutch National Mobility Panel survey data from the period 1984 through 1987 to investigate alternative time-series models of trip generation rates. Household weekly trip rates for both total trips and social-recreation trips were estimated using weighted least squares regression for a range of model structures, including:

1. a cross-sectional model, in which the same equation holds in each time period;
2. a lagged independent variables model, in which the independent (i.e., explanatory) variables from one or more previous time periods enter the equation, along with the independent variables for the current time period;
3. a lagged dependent variables model, in which the value of the dependent variable (i.e., the trip rate) for the previous time period enters as an explanatory variable in the current time period equation; and
4. serial correlation models, with and without lagged dependent variables, in which the error terms in the different time periods are assumed to be correlated due to unobserved variables which affect trip rates and which tend to remain constant over

time.

The results of the analysis strongly indicate that lagged independent variables contribute very little to the explanatory power of the model, whereas the introduction of the lagged dependent variable does consistently and dramatically improve the model fit relative to the cross-sectional case. In particular, it appears that the poorer the fit of the cross-sectional model, the greater the improvement obtained by including the lagged dependent variable (probably since the lagged dependent variable captures much of the idiosyncratic household-to-household variation which would not otherwise be systematically explainable). The introduction of serial correlation, however, indicates that of the three effects considered, it is the most important. That is, the model with serial correlation included but with the lagged dependent variable excluded fits the data significantly better than the lagged dependent variable model without serial correlation. Further, adding the lagged dependent variable to the serial correlation model results in only a modest increase in goodness-of-fit.

Thus, the analysis provides strong evidence of time-dependencies in trip generation.[2] In particular, this evidence suggests that much of this time-dependency is due to serial correlation; that is, omitted variables that tend to be longitudinally correlated. While not discussed by the author and while certainly derived from a very different modelling approach, it would seem that this result is relatively consistent with the Kostyniuk and Kitamura cohort analysis result of "cohort effects" over time; that is, of people "carrying their behaviour with them" over time. In particular, to the extent that this cohort effect may be at least partially unobservable (i.e., not captured within our usual set of explanatory variables) it will tend to give rise to serial correlation effects in time-series regressions.

Allaman & Tardiff [1983]: Using the 1977 Baltimore Disaggregate Data Set, the authors explored the impact of household structure and residential zone characteristics on household trip generation rates. Household structure is characterized in terms of the number of household members in each of five age categories,[3] combined with "household type" dummy variables.[4] Residential zone

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[2] It is worth noting that the total trip serial correlation models, developed with quite a comprehensive set of explanatory variables, achieve R^2 values in excess of 0.75 -- something few other trip generation models accomplish.

[3] Age categories used: 12-19, 20-34, 35-54, 55-64, 65 plus.

variables included in the analysis are: population density and dummy variables indicating whether the household resides within the City of Baltimore or not and whether the household has moved into the zone within the past six months. Household trip generation regression equations were developed for both "activity-based" trips (i.e., trips categorized by destination purpose, regardless of origin location) and "home-based" trips (i.e., trips which begin or end at home) for a range of trip purposes[5]. In each case, three levels of models were developed: a "base" model which is a function of "traditional" trip generation factors (number of household vehicles, household income, and number of persons (12 years or older) in the household); a model in which the household structure variables are included; and a model in which the residential zone variables are included, as well as the household structure variables.

In general, the authors found that both the household structure variables and the residential zone variables contribute in a statistically significant way to the explanatory power of the regression equations, with the household structure variables tending to be the more important of the two types of variables. In addition, household income contributes little to the model once these other variables are included. The authors then proceed to speculate about the implications of these findings for the evolution of trip generation rates over time as the population ages and household structures evolve, much in the same way as many of the other authors reviewed above have done.

It is interesting to note that R^2 value achieved by Allaman and Tardiff for home-based work trips is 0.545. This can be compared with the R^2 value achieved in this study for home-to-work trips of 0.560 (cf. equation [1], page 15). The Allaman and Tardiff model, however, possesses 23 coefficients (including the intercept), whereas equation [1] possesses only 3. Further, it is inconceivable that the task of forecasting future numbers of full-time and part-time workers (the data required to use equation [1] in a forecasting mode) can be more onerous or error-prone than that involved in estimating future joint distributions of the 22 explanatory variables required by the Allaman and Tardiff model. This comparison of these two models thus provides a relatively strong endorsement of the "labour force based" approach to work trip generation modelling which is more

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[4] Categories used: male living alone; female living alone; unrelated individuals; couple with ages within 10 years apart; single-parent household; nuclear family (married couple with children under 20); adult family with children (two or more adults with children); and adult family without children (adults with same last names, no children).

[5] Trip purposes considered: total trips, "return home" (activity-based trips only); work; shopping; personal business; entertainment/community; social; and "serve passenger".

or less standard practice within the GTA as opposed to the more traditional (and still standard American) approach of expressing work trip rates as a function of variables such as household size and auto ownership levels.

Finally, the Allaman and Tardiff R^2 values for their non-work home-based trip models range in value from 0.064 (for personal business trips) to 0.196 (for entertainment/community trips), which are considerably better than those achieved in this study's analysis of household home-based shopping trip rates (cf. Tables 2.2, 2.3 and 2.4). This indicates that improved specifications such as Allaman and Tardiff's can lead to improved explanation of non-work trip-making with a linear regression modelling framework. It must, however, also be noted that this improvement, relatively substantial though it is, in absolute terms is still small, with 80 - 90% of the household-to-household variability in non-work trip rates still being left unexplained by the model. Thus, the general conclusion presented in Chapter 2, that linear regressions are inadequate as models of household non-work trip generation behaviour would still appear to hold.

Denk & Boyle [1982]: This report also deals with the role of household structure (in this case, "household structure" is treated by the authors as being synonymous with "lifecycle") on total household trip-making (in this case measured in terms of total household vehicle miles travelled, VMT). In particular, the research focuses on the question of whether households with high travel rates[6] can be identified primarily on the basis of household structure (lifecycle). The study is also relatively unique in that it does not simply assume a household structure categorization based on a priori assumptions, but rather explores a range of possible categorizations using both descriptive/judgemental methods and more "objective" statistical analysis methods. Data from the 1973 Niagara Frontier Transportation Committee (NFTC) Home Interview Survey (in the greater Buffalo region) were used for the majority of the analysis, with the final model developed then being applied to the Rochester area and compared with travel rates observed in the 1974 Genesee Transportation Committee (GTC) Home Interview Study (presumably the same dataset as used by Kostyniuk and Kitamura in their paper). Key results from this paper include:

1. The "best" categorization of household structure is a twelve-category scheme based on employment status of the household head (full-time versus not-full-time), presence of a spouse (yes versus no), and the age of the oldest child (16 or over, under 16, no children).

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[6] It has been observed that about 15% of the households in American cities account for over 45% of total vehicle travel. [Gorman, 1980]

2. Full-time worker status for the household head, presence of a spouse and presence/increasing age of oldest child all have positive impacts on household trip-making activity (all increase averge household VMT).

3. The results obtained for Buffalo appear to be relatively transferrable, since the Buffalo model applied to Rochester yielded the same rank ordering of household classes with respect to average VMT (and, indeed, very comparable average VMT's per household class) and were very comparable in their ability to explain the observed variance in the Rochester dataset (in both cases about 16% of the variance was explained by the model).

4. Household structure alone does not seem to be able to identify "high travel" households, since the highest travel category which accounts for 14 to 19% of the households in the two samples generates only about 30% of the total VMT (whereas the maintained hypothesis is that the "top 15%" should account for at least 45% of the travel). Thus, other factors must also contribute to the explanation of "high travel" activity.

McDonald & Stopher [1983]: In this study, the authors used a combination of analysis of variance (ANOVA) and multiple classification analysis (MCA) to develop a household-level cross-classification model[7] for home-based work, shopping, school and other trips, and non-home-based trips. The data used to develop the model comes from a 1982 survey conducted in seven counties in Michigan. In contrast to the Allaman and Tardiff (and Denk and Boyle) results, McDonald and Stopher found that the most important explanatory variables across all trip purposes considered were number of household vehicles, household size, income and housing type.[8] Household structure, patterned as closely as possible after the Allaman and Tardiff construction, did not improve the performance of the models for any trip purpose relative to the "base" models constructed using only household size and number of autos. Further, inclusion of the household structure effect resulted in a somewhat ill-behaved model. The authors therefore question the utility of household structure variables in trip generation models, particularly given the practical difficulty involved in constructing these variables for forecasting purposes.

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[7] See Stopher and McDonald [1983] for details of this approach. For a recent appliction of this approach within Ontario to develop a person-based trip generation model see Tranplan [1990].

[8] In addition, for the special case of home-based work trips, the number of workers in the household is by far the most significant explanatory variable. The authors do not focus on this result, however, since the variable has little explanatory power with respect to the other trip purposes, and they are interested in developing a set of variables which are "best" across all trip purposes (although why this is a desirable approach is not made clear).

Brunso & Hartgen [1984]: This study applies the same statistical analysis method used in the Denk and Boyle study to data from a 1983 New York State wide survey of 1,503 individuals. Since individuals rather than households were sampled, the trip rate analysis had to be at the person-level rather than the household-level. The nature of the survey also restricted somewhat the construction of household structure characteristics to include in the analysis. Based on their analysis, as well as an interesting review of the available literature, the authors concluded the following:

1. The average New York State weekday daily trip rate per adult in 1983 was 3.0, which was unchanged from the results obtained in earlier surveys in Buffalo (3.0 in 1973) and Rochester (3.1 in 1974). Thus, considerable stability in aggregate trip rates occurred over the decade 1973-1983.

2. There is no significant variation in average trip rates geographically within New York State, either between "upstate" (New York City and Long Island) and "downstate" (remainder of the state) sections, or among areas designated as being urban, suburban, small town and rural.

3. In contrast to the Denk and Boyle findings, but consistent with the findings of McDonald and Stopher, they found no statistically significant household structure/lifecycle effects on person trip rates.[9]

4. Factors found to be significant in explaining adult daily trip rates include: income, sex, employment status, number of household vehicles, and presence of children under 18 years of age.

Based on these results, the authors conclude that trip rates are determined primarily by demographic factors which tend to be geographically transferrable. They also hypothesize, based primarily on the comparison of 1973 to 1983 average adult trip rates that these factors are temporally transferrable (i.e., relatively constant) over time; that is, in the terminology of Kostyniuk and Kitamura, that significant cohort effects may not exist. It should be noted, however, that this conclusion is more hypothesis than "proven fact". Further, even if this were true for New York State during the 1970's, it need not hold true there or elsewhere in the future, particularly in the long run.

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[9] Note, however, that the Denk and Boyle results were obtained from a household-based analysis. Further, Brunso and Hartgen observe that their result may be limited by the lack of household-level information in the data.

Town [1980]: This report summarizes travel behaviour within Great Britain, as characterized by the 1975/76 National Travel Survey (NTS, a seven-day, nationwide travel diary survey of all people 3 years of age or older in 15,343 households). Table 3.3 summarizes the results presented with respect to trip rates and trip distances by purpose and person type. In general, these results are consistent with the trip-making patterns typically observed in the North American context.

Downes, Johnsen & Morrell [1978]: The objective of the research documented in this report is to compare household-based and person-based models of trip generation. The modelling method used is a quite sophisticated cross-classification methodology in which first-, second-, and higher-order interactions between the classifying variables are included in a step-wise fashion, based on explanatory power (i.e., only statistically significant effects are included, with these effects entering in order of significance). In addition, the method automatically tests for linearity in a given effect, and in cases in which a given variable is found to have a linear effect, the discrete set of classes associated with this effect are replaced by a "continuous" variable in a regression-like way (leading to both a more eficient model and a more practical one to use in forecasting applications). Two surveys from the Reading area, one from 1962 and one from 1971, are used in the analysis.

In general, Downes, et al. found that both household-based and person-based models performed about equally well in terms of their goodness-of-fit characteristics, with R^2 values typically in the 0.55 to 0.60 range for home-based total trips and in the 0.50 to 0.55 range for home-based work trips.[10] The person-based models, however, typically produced fewer second- and higher-order interactions. Further, an analysis of model residuals indicates that the household-based model errors tend to vary with household size, whereas the person-based model errors tended to more constant over the range of explanatory variable values. Thus, the authors conclude that person-based models are preferred over household-based models, for both practical and statistical reasons. They do, however, also recognize that some issues exist with respect to the specification of person-level explanatory variables relating to the allocation of household-level attributes (income, auto availability, etc.) to the person level.

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[10] Note again the consistency in the goodness-of-fit values for disaggregate home-based trip models. As with the Allaman and Tardiff results, household size, income and auto ownership type variables are used by Downes, et al. Again, it would appear that the more complicated model does not out-perform the considerably simpler labour-force based model used in this study.

Table 3.3

Summary of British Trip Rates and Trip Distances, 1975/76

Source: Towne [1980]

Daily journey rates according to purpose and social group

Social group: \ Purpose:	Work	Shopping	Social	Recreation	Education	Personal business	Escort	Other	All purposes	Number of respondents	Number of journeys
Whole population	0.56	0.49	0.39	0.29	0.25	0.24	0.14	0.21	2.57	27906	71600
Working adults	1.31	0.38	0.41	0.26	*	0.21	0.16	0.44	3.17	8867	28089
Young children	*	0.29	0.30	0.32	1.03	0.17	*(0.03)*	0.05	2.19	3024	6614
Teenagers	0.07	0.35	0.38	0.45	1.07	0.27	*(0.01)*	0.07	2.67	2888	7700
Young adults	0.90	0.36	0.60	0.35	0.23	0.25	*(0.05)*	0.27	3.01	1388	4172
The elderly	0.09	0.57	0.30	0.23	*	0.26	0.03	0.09	1.57	4096	6438
Housewives	*	0.87	0.46	0.26	*(0.01)*	0.28	0.34	0.07	2.29	3350	7674
Low income adults	0.45	0.60	0.45	0.22	*(0.02)*	0.28	0.13	0.18	2.33	1498	3486

NTS 1975/76

Notes for all tables: (i) Journey rates or distances in *(italics)* are based on < 100 journeys

(ii) * denotes < 0.005 journeys

Journey rates per day by all modes according to social group and household car ownership

Social group:	Number of household cars: None	One	Two or more	All households	Number of respondents	Number of journeys
Whole population	2.06	2.82	3.07	2.57	27887	71573
Working adults	2.65	3.33	3.48	3.17	8862	28072
Young children	1.83	2.32	2.45	2.19	3024	6616
Teenagers	2.40	2.78	2.81	2.67	2883	7692
Young adults	2.62	3.07	3.41	3.01	1388	4173
The elderly	1.43	1.90	1.80	1.57	4095	6440
Housewives	1.93	2.44	2.72	2.29	3348	7672
Low income adults	2.19	2.71	*(2.62)*	2.33	1499	3489

NTS 1975/76

Mean distances (in kilometres) of journeys by all modes according to social group and household car ownership

Social group:	Number of household cars: None	One	Two or more	All households
Whole population	5.4	8.6	11.4	8.1
Working adults	7.2	11.0	14.7	10.8
Young children	3.0	5.6	7.5	5.2
Teenagers	4.1	5.9	7.8	5.6
Young adults	7.3	8.9	11.0	9.0
The elderly	4.7	5.4	10.4	6.3
Housewives	4.6	6.8	9.3	6.5
Low income adults	5.2	8.[illegible]	*(14.6)*	6.4

NTS 1975/76

Mean distance (in km) of journeys by all modes according to purpose and social group

Social group: \ Purpose:	Work	Shopping	Social	Recreation	Education	Personal business	Escort	Other	All purposes
Whole population	8.3	4.3	9.4	10.2	3.3	5.6	5.4	21.8	8.1
Working adults	9.3	5.4	11.5	12.3	*(14.7)*	7.5	7.4	20.9	10.8
Young children	*(10.4)*	4.4	8.7	9.1	1.6	4.6	*(7.5)*	37.7	5.2
Teenagers	5.7	4.3	6.1	7.9	3.9	3.4	*(9.4)*	30.9	5.6
Young adults	7.9	4.6	8.6	11.6	10.1	7.2	*(10.5)*	16.6	9.0
The elderly	6.1	3.4	8.3	7.6	*(6.6)*	4.2	6.0	19.7	6.3
Housewives	*(3.3)*	3.7	9.1	9.8	*(8.4)*	5.1	3.3	33.8	6.5
Low income adults	5.3	3.4	8.2	8.8	*(9.4)*	5.3	3.5	15.8	6.4

NTS 1975/76

CHAPTER 4

SUMMARY, CONCLUSIONS AND FUTURE WORK

4.1 Summary of Results and Implications for Trip Generation Modelling

Over and above the detailed findings presented in Chapters 2 and 3, there are perhaps three general results that have emerged from the work documented within this report. These are:

1. Relatively simple regression models at either the household or the zone level can be used to represent home-based work and school trip making.

2. Non-work trip generation is far more difficult to model, given the complexity inherent in non-work travel behaviour. It can, however, perhaps be best represented at the level of the individual trip-maker as a function of the person's age, sex and residential location.

3. A simple "trip-end density" measure provides a useful means of classifying spatial locations as a basis for trip generation analysis.

The following two sub-sections discuss these findings in some additional detail, with respect to work and non-work trips, respectively.

4.1.1 Work Trip Generation

Consider variability in work trip generation rates exists at the level of the individual trip-maker. Factors influencing this variability include the age and sex of the individual, the modal choices available to the individual, and the individual's residential location (characterized within this study in terms of the "urban density" of the individual's zone of residence). With the exception of the modal choice characteristics, however, the majority of this variability is due to variations in labour force participation rates by age, sex and location, since once the population has been mapped into full-time and part-time workers, very reliable relationships exist between home-end work trip rates and the number of full- and part-time workers, at either the household or the zone level (with, optionally a further disaggregation by gender). Similarly, work-end trip rates can be reliably estimated as a simple function of zonal employment.[1]

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[1] Undoubtedly the strength of this work-end relationship would be improved if zonal employment totals could be disaggregated into full-time and part-time workers, ideally by gender.

Further, changes over time may be more likely to occur with respect to labour force participation rates (e.g., as younger, workplace-oriented women age) and/or full-time/part-time splits within the labour market (e.g., if the trend towards part-time employment, job-sharing, etc. continues) than with respect to worker trip rates per se.[2] Finally, modal choice effects inherently depend on both the trip origin and destination (since it is the combination of these two which determine the modes available for the trip and the modal levels of service offered). Thus, modal choice effects presumably are best handled at a "post-distribution" phase of the analysis, rather than within the trip generation phase per se.

For all of these reasons, it appears that a sensible approach to work trip generation modelling involves the following general steps:

1. Predict the number of full-time and part-time workers by sex on a (small) zone basis as a function of the age-sex profile of the resident population and the labour force participation rate distribution expressed as a function of age and sex.

2. Predict the number of 24-hour home-to-work trips produced in each residential zone as a function of the number of full-time and part-time workers (disaggregated by sex, if desired; e.g., equations [5] and [6], Table 2.6) in the zone, estimated in step 1.

3. Predict the number of 24-hour home-to-work trips attracted to each employment zone as a function of the number of jobs located in the zone (e.g., equation [7], Table 2.6).

4. Factor work trips by mode and peak/off-peak periods of travel in subsequent stages of the analysis, preferrably after the trip distribution stage.[3]

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[2] Although factors may well exist to alter these rates over time as well. These might include telecommunications impacts that would reduce the need for workers to commute to a central workplace, changes in the number of days either full-time or part-time workers work on average (due to flex-time programs, for example), etc. The strength and timing of such impacts are, however, difficult to ascertain, and certainly to date such trends (to the extent that they exist) have had relatively little impact on the majority of commuters.

[3] The peak/off-peak issue has not been focussed on in this report, and, in particular, the determination of an "optimal" method of determining peak/off-peak splits is beyond the scope of the current study. For present purposes, it is sufficient to observe that modelling work trip generation on a 24-hour basis has considerable theoretical and practical appeal and is strongly preferred over the direct modelling of peak-period (or peak-hour) trips (in which case strong assumptions of constant peak period behaviour over time must be made). The case is less clear, for example, for the trip distribution stage of the process, in which one might argue that a direct peak period model has some merit.

This recommended approach has the advantage of being sensitive to demographic changes over time (which have been shown in study after study to be central to the understanding of trip generation trends), while maintaining a simple, reliable set of trip generation relationships. The major difficulty of the approach, of course, involves generating future age-sex profiles by zone and future labour force participation rate distributions by age and sex. It is suggested that these distributions may be computed by urban density class in a relatively straightforward and (hopefully) reliable way from available data. This suggestion is pursued in detail in Volume III of this report series, in which an operational model of work trip generation based on these concepts is developed and applied to the GTA.

4.1.2 Non-Work Trip Generation

As with work trips, considerable variability exists at the personal level in non-work trip rates as a function of age, sex, modal availability, and spatial location (urban density). Unlike work trips, however, this variability is not successfully "aggregated away" by moving to the household or the zonal level. In particular, household-level regression models manage to explain on 2 to 4 percent of the total variability in household weekday shopping trip generation -- a totally unacceptable result. The one exception to this result is the school trip purpose, for which reliable trip generation relationships at either the household or the personal level are achieved. This is not surprising, given the regular, "work-like" nature of school travel.

For many planning purposes, non-work travel is of relatively minor importance, and hence this component of travel demand is often modelled in a very simple fashion, or else is simply ignored altogether. If, however, one is interested in assessing the overall magnitude of travel within an urban area, then non-work travel certainly cannot be ignored. Given the complexity of non-work travel behaviour, however, and the relatively poor operational models of this behaviour currently available,[4] a suggested approach for modelling non-work travel consists of the following steps:

1. Split non-work travel into three components: home-based school trips, home-based "other" (i.e., non-work and non-school) trips, and work-based "other". This latter category is of importance, since a significant proportion of travel to non-work locations is, in fact, work-based rather than home-based in nature.

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[4] A considerable and quite complex theoretical literature exists with respect to non-work travel. In general, however, remarkably little of this literature has been (or can be) applied within practical planning environments.

2. Generate the home-based trips for school and "other" purposes by mode on a per person basis as a function of the person's age, sex and residential zone density class (i.e., use trip rate distributions similar to Figures 2.15, 2.16 and 2.17). This, in turn, requires the generation of zonal population age-sex profiles in the same manner as required for the work trip generation analysis.

3. Generate work-based trips as a function of the total employment in the work zone.

4. If necessary, estimate non-home-based trips as a function of the population and employment located in the given zone.[5]

The combination of modal choice within the trip generation phase (in contradiction of the case just made for avoiding such an approach in the work trip case) is justified partially on the grounds of simplicity but also partially on the grounds that transit usage for non-work travel tends to be more dependent on socio-economic factors and less on level of service considerations (i.e., a higher proportion of non-work transit users tend to be captive to the system) and hence is more readily combined within the trip generation phase of the analysis. It must be recognized, however, that this approach tends to "build in" existing modal split characteristics into forecasts of future travel behaviour to a far greater degree, both conceptually and in practical terms, than the work trip assumption of a separate, post-distribution modal split component.

This suggested approach does, however, provide a mechanism for estimating future home-based and work-based non-work travel with essentially the same inputs as required for the work trip analysis and in a way which is sensitive to demographic and urban structure changes over time.

4.2 Directions for Future Research

Although a quite extensive analysis of the TTS database has been undertaken within the current study, the work to date has in many ways only scratched the surface of what can, in fact, be explored within this database. In particular, promising tasks or interesting research issues that have emerged from the current project include the following:

1. There is a need to conduct a thorough analysis of variance of both person-based and

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[5] Although not shown in this report, zonal regressions of non-home-based trip productions and attractions versus zonal population and employment yield somewhat reasonable results, with significant coefficients (typically employment is the more significant of the two variables) and R^2 values of approximately 0.37. As discussed in detail in Volume III, such non-home-based trip generations are not required within the analysis adopted in this study.

household-level trip generation to complement and extend the analyses presented within this study.

2. The measurement and use of the concept of accessibility as an explanatory variable in trip generation models requires thorough examination.

3. More realistic (yet practical) methods of modelling non-work trip generation need to be developed. One approach to this might involve the development of explicitly probabilistic models of non-work trip generation (in recognition of the inherently stochastic nature of non-work travel processes), perhaps combined within some relatively simple "simulation" algorithm. While this sounds extremely complicated by conventional trip generation modelling standards, it may well be necessary to achieve a significantly improved representation of this important but complex component of urban travel.

4. The relationship between household structure, labour force participation rate, and urban density (and/or accessibility) needs to be examined in more detail, particularly with respect to the extent that this relationship can be expected remain constant over time (or, the extent to which it can be expected to evolve in predictable ways over time).

REFERENCES

Allaman, P.M. and T.J. Tardiff (1983) "Usefulness of Indicators of Household Structure and Characteristics of Residential Zones in Trip Generation Models", presented at the 61st Annual Meeting of the Transportation Research Board, Washington, D.C., January.

Bailey, G.K., E.J. Miller and G.N. Steuart (1990) *Understanding Urban Travel Growth in the Greater Toronto Area, Volume I, Travel to the Central Area of Toronto: Descriptive Analysis & Policy Implications*, project report to the Research and Development Branch, Ontario Ministry of Transportation, Project No. 25194, Toronto: University of Toronto - York University Joint Program in Transportation, March.

Barnard, P.O. and R.E. Brindle (1987) "A Review and Critique of Current Methods Used to Predict Traffic Generation with Some Accompanying Suggestions on Alternative Approaches", *Transportation Planning and Technology*, Vol. 11, pp. 273-288.

Brunso, J.M. and D.T. Hartgen (1984) "An Update on Household Reported Trip Generation Rates", presented at the 62nd Annual Meeting of the Transportation Research Board, Washington, D.C., January.

Bussiere, Y. (1984) "Population Aging and Transportation Demand: A Montreal Case Study for 1978-1991", *Ekistics*, Vol. 51, No. 306, May/June, pp. 238-241.

Busiere, Y., R. Marcoux and M. Tessier (1987) "Demographe et Demande de Transport des Personnes: Method de Projection Elaboree a Partir du Cas Montrealais: 1981-1996", *Canadian Journal of Regional Science*, Vol. X, No. 1, Spring, pp. 19-40.

Chapleau, R. and D. Girard (1986) *Effects of Population Aging and Urban Dispersion on the Use of Urban Transport in the Future*, Publication No. 461, Montreal: Centre for Transport Research, University of Montreal, April.

Delcan Corporation (1989a) *TRANS Trip Generation Technical Report*, prepared for TRANS Joint Technical Committee on Transportation Systems Planning, Ottawa, October.

Delcan Corporation (1989b) *TRANS Trip Generation Manual*, prepared for TRANS Joint Technical Committee on Transportation Systems Planning, Ottawa, October.

Denk, A.J. and D.K. Boyle (1982) *Life Cycle Characteristics of High Travel Households*, Report No. 15, Albany, N.Y.: Planning Division, New York State Department of Transportation, August.

Downes, J.D., S. Johnsen and D. Morrell (1978) *Household and Person Trip Generation Models*, TRL Supplementary Report 401, Crowthorne, Berkshire, U.K.: Transport and Road Research Laboratory.

Gorman, R. (1980) *Household Characteristics and the Determinants of Travel Behavior*, Washinton, D.C.: Federal Highway Administration, U.S. Department of Transportation.

Greater Vancouver Regional District (1988) *Transportation Modelling Procedure Manual, Version 1.0*, Burnaby, B.C.: GVRD Development Services, May.

Institute of Transportation Engineers (1987) *Trip Generation, Fourth Edition*, Washington, D.C.

Jea, D. (1990) *A Trip Prediction Model Based on Density Stratification of the Greater Toronto Area*, M.A.Sc. thesis, Toronto: Department of Civil Engineering, University of Toronto.

Kitamura, R. (1988) "Formulation of Trip Generation Models Using Panel Data", *Transportation Research Record 1203*, Washington, D.C.: Transportation Research Board, pp. 60-68.

Kostyniuk, L.P. and R. Kitamura (1987) "Effects of Aging and Motorization on Trvel Behavior: An Exploration", presented at the 66th Annual Meeting of the Transportation Research Board, Washington, D.C., January.

McDonald, K.G. and P.R. Stopher (1983) "Some Contrary Indications for the Use of Household Structure in Trip-Generation Analysis", *Transportation Research Record 944*, Washington, D.C.: Transportation Research Board, pp. 92-100.

Miller, E.J., G.N. Steuart and D. Jea (1990) *Understanding Urban Travel Growth in the Greater Toronto Area, Volume III, Future Travel Trends andTheir Implications for Transportation Policies in the Greater Toronto Area*, project report to the Research and Development Branch, Ontario Ministry of Transportation, Project No. 25194, Toronto: University of Toronto - York University Joint Program in Transportation, March.

Ministry of Transportation, Ontario (1987a) *The Transportation Tomorrow Survey, Bulletin, September 1987*, Volume 1, Number 1, Toronto.

Ministry of Transportation, Ontario (1987b) *The Transportation Tomorrow Survey, Design and Conduct of the Survey*, Toronto.

Ministry of Transportation, Ontario (1988a) *The Transportation Tomorrow Survey, Data Validation*, Toronto.

Ministry of Transportation, Ontario (1988b) *The Transportation Tomorrow Survey, Data Guide Version 2.2*, Toronto.

Monzon, J., K. Goulias and R. Kitamura (1989) "Trip Generation Models for Infrequent Trips", presented at the 68th Annual Meeting of the Transportation Research Board, Washinton, D.C., January.

Stopher, P.R. and K.G. McDonald (1983) "Trip Generation by Cross-Classification: An Alternative Methodology", *Transportation Research Record 944*, Washington, D.C.: Transportation Research Board, pp. 88-91.

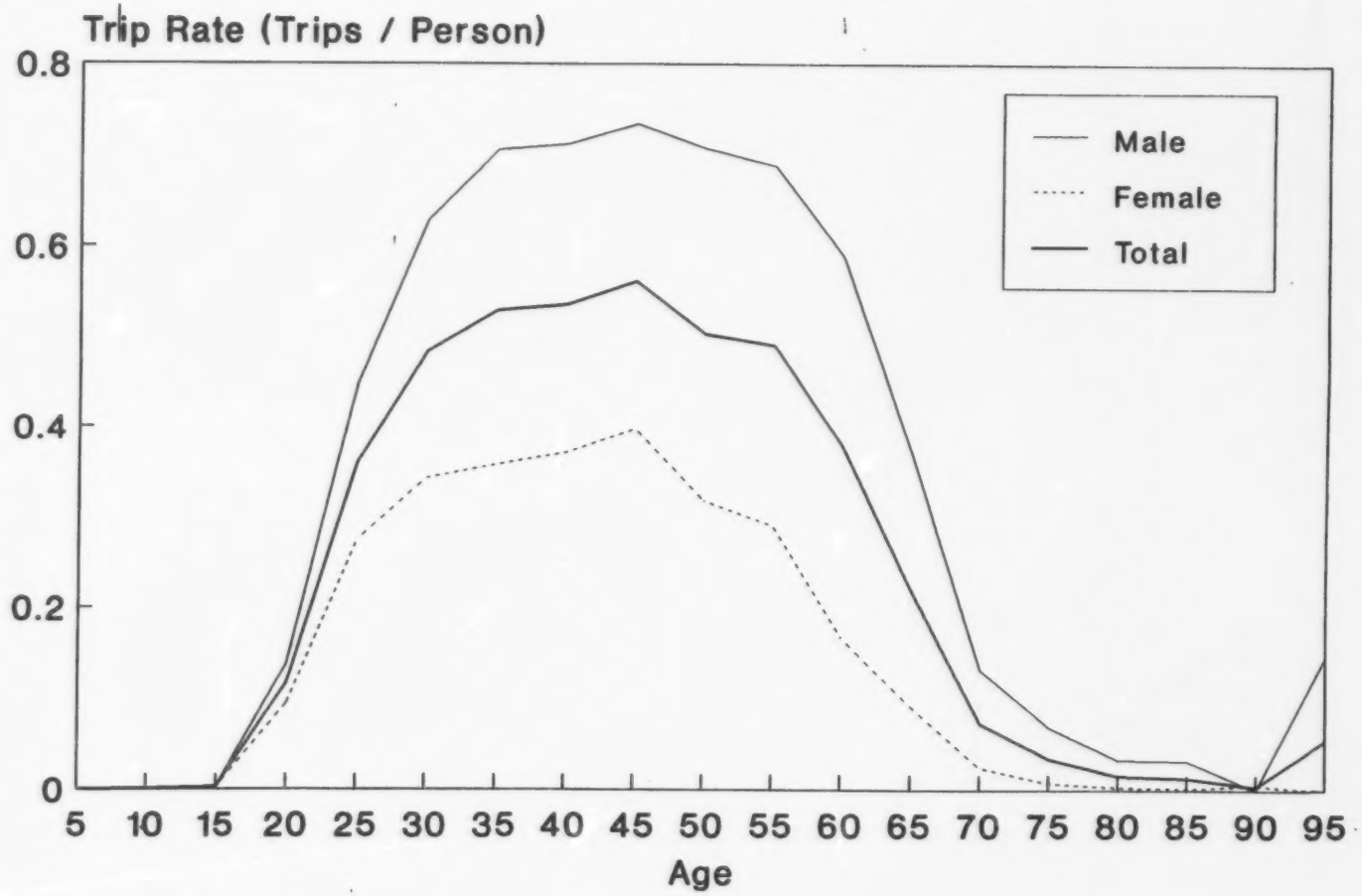
Tranplan Associates (1990) *Niagara, Waterloo, London Travel Survey*, on-going project for the Regional Municipalities of Niagara, Waterloo and London, Oakville.

Town, S.W. (1980) *The Social Distribution of Mobility and Travel Patterns*, TRRL Laboratory Report 948, Crowthorne, Berkshire, U.K.: Transport and Road Research Laboratory.

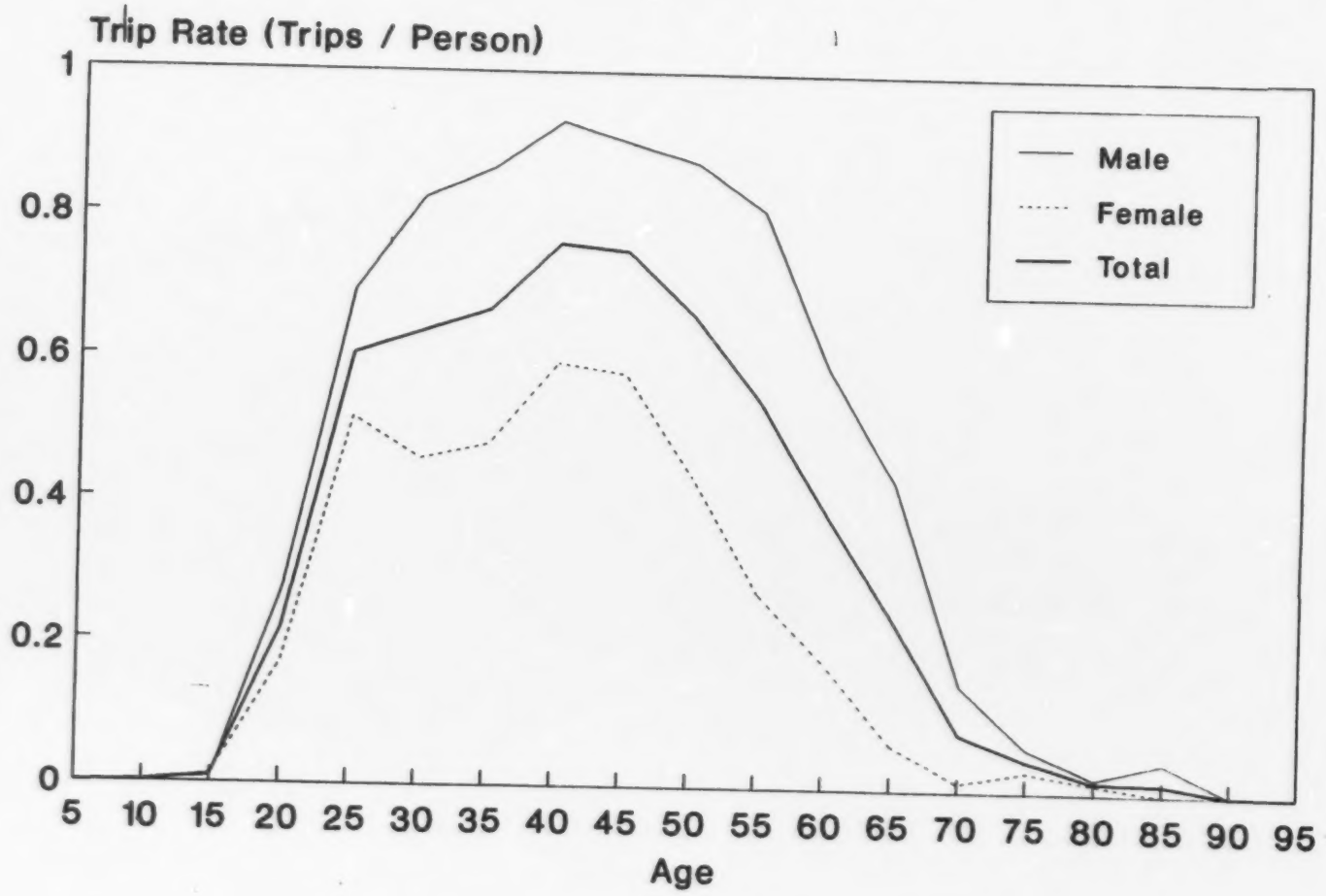
APPENDIX A

TRIP RATES BY AGE AND SEX BY TRIP PURPOSE, MODE AND REGI0NAL MUNICIPALITY

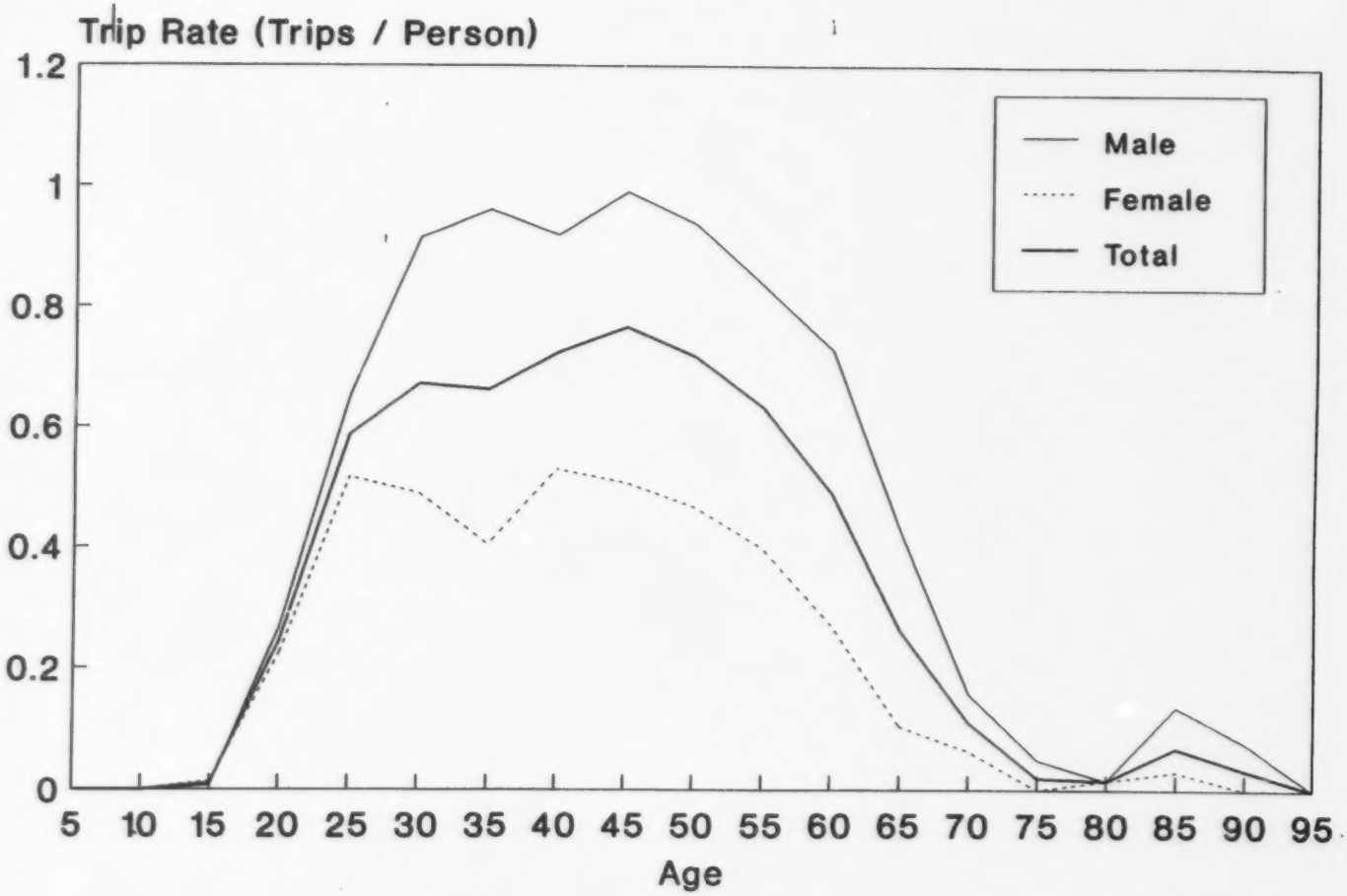
Auto Trip Rates by Age for Work Trips
for METRO Region



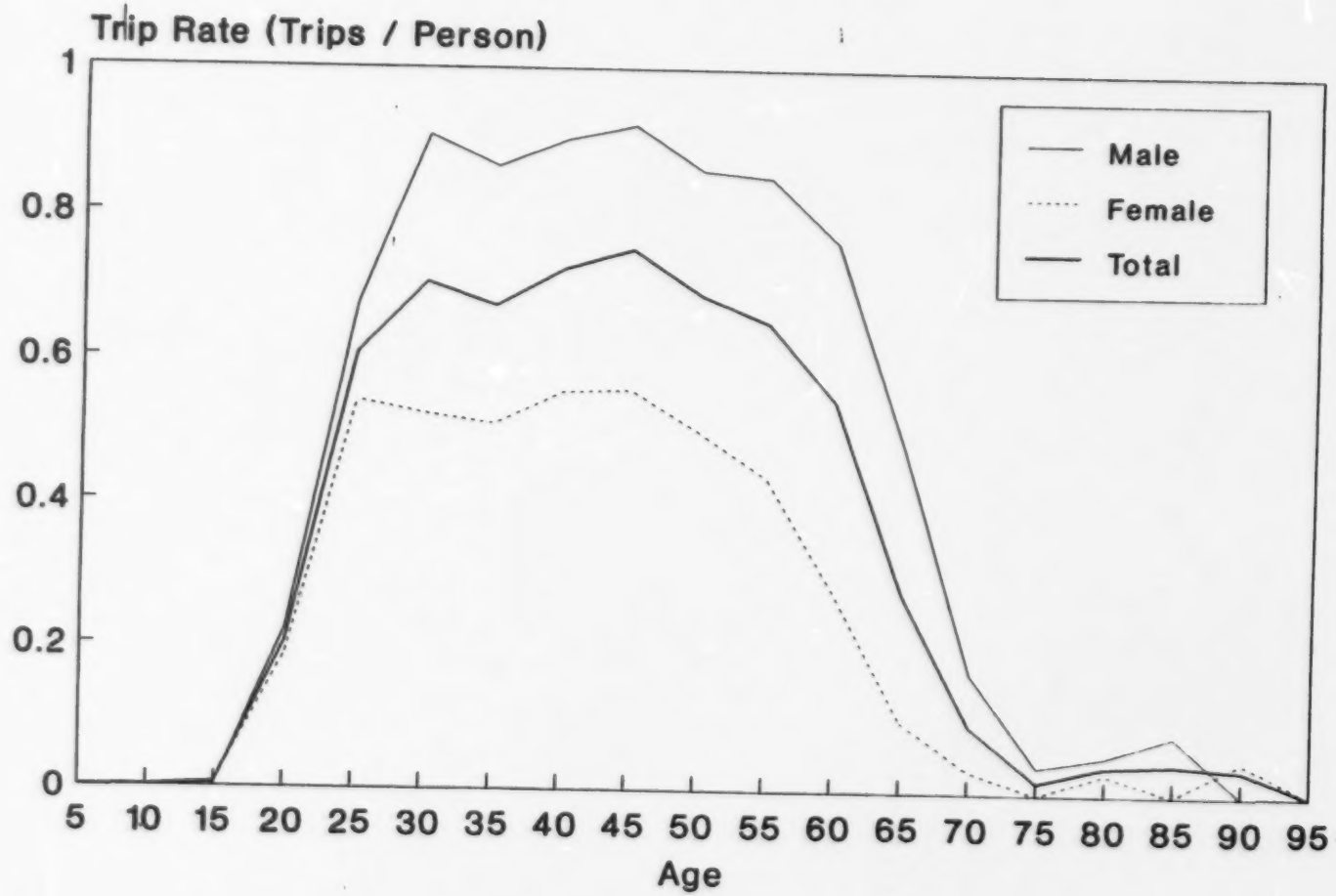
Auto Trip Rates by Age for Work Trips
for DURHAM Region



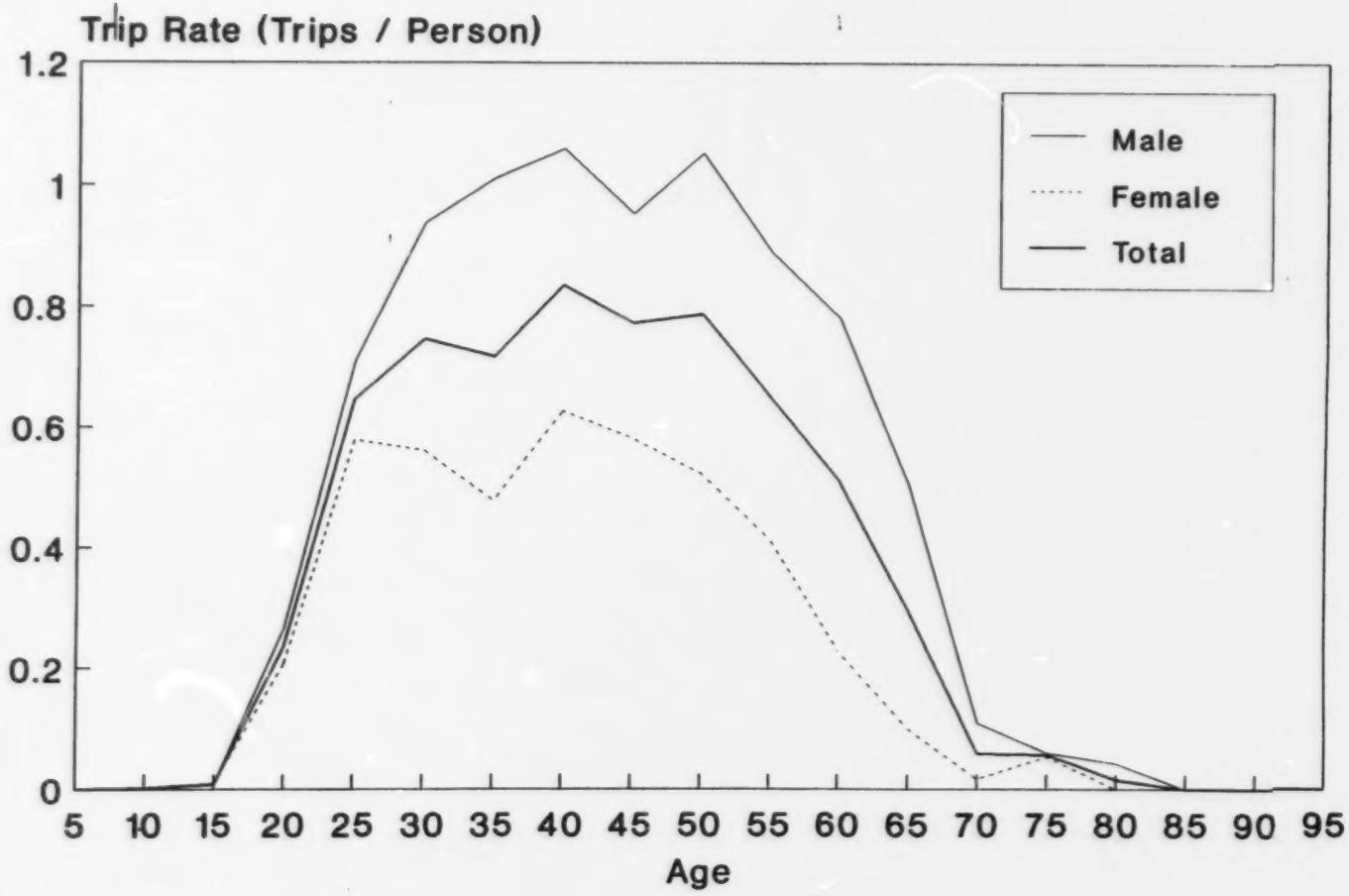
Auto Trip Rates by Age for Work Trips
for YORK Region



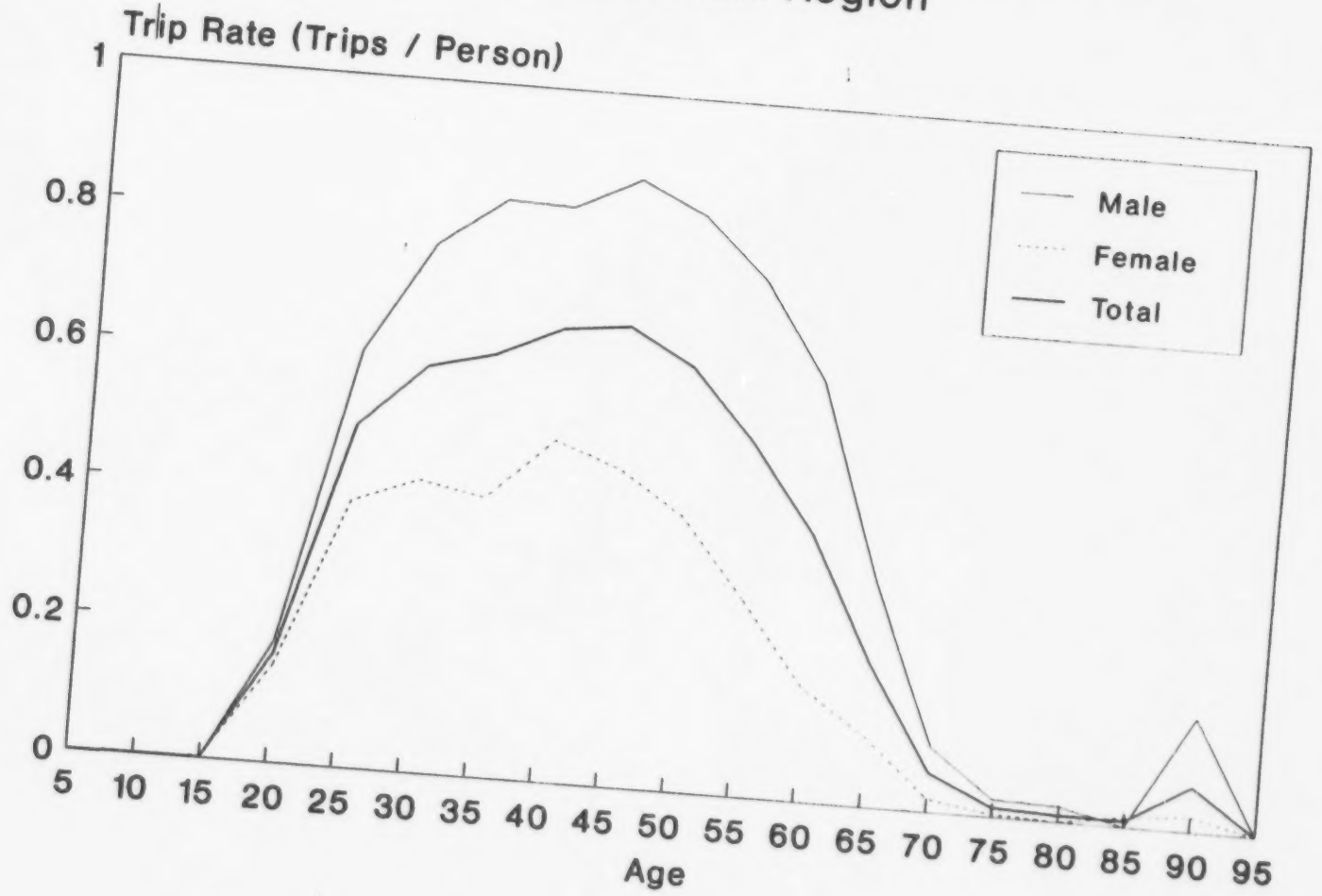
Auto Trip Rates by Age for Work Trips
for PEEL Region



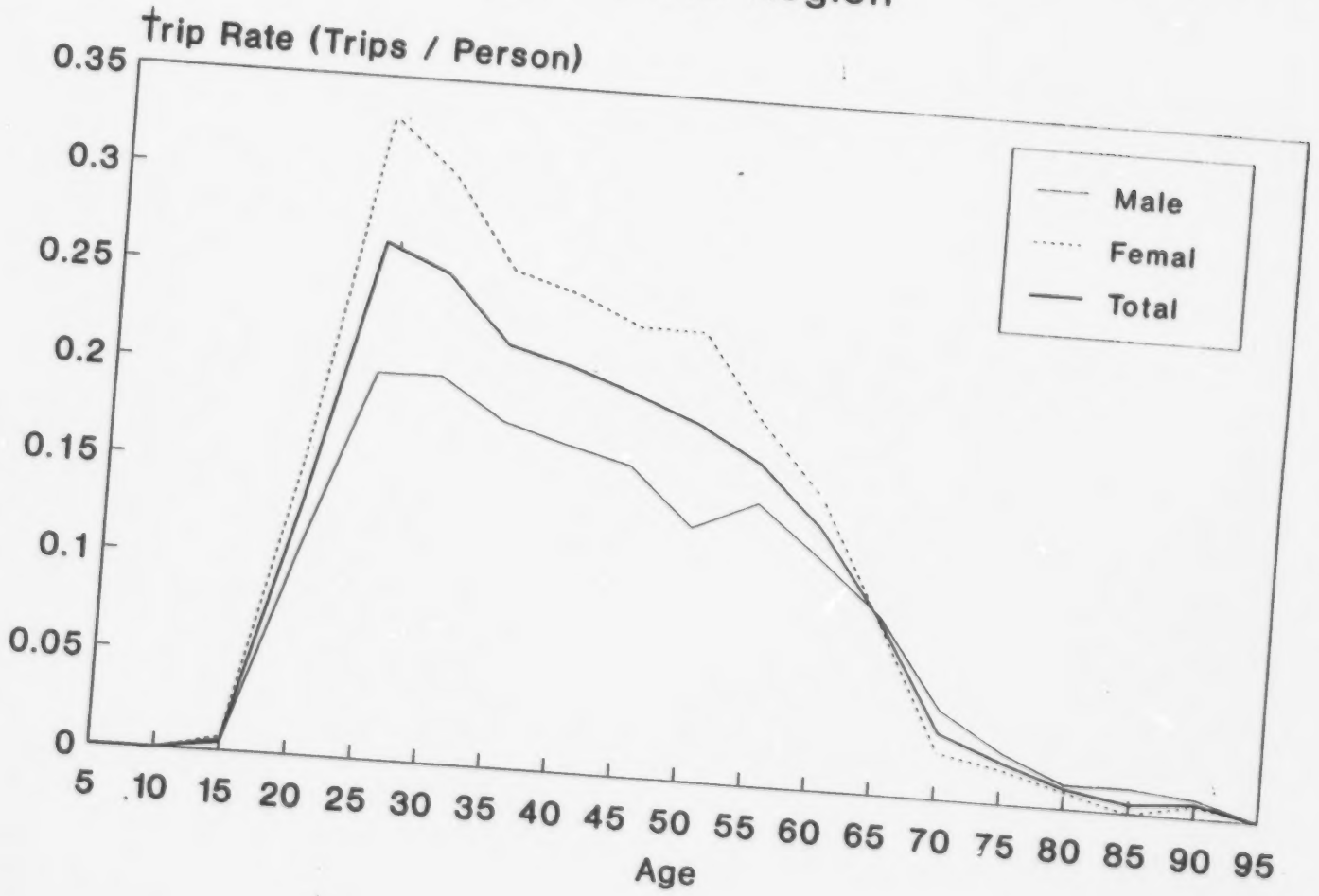
Auto Trip Rates by Age for Work Trips
for HALTON Region



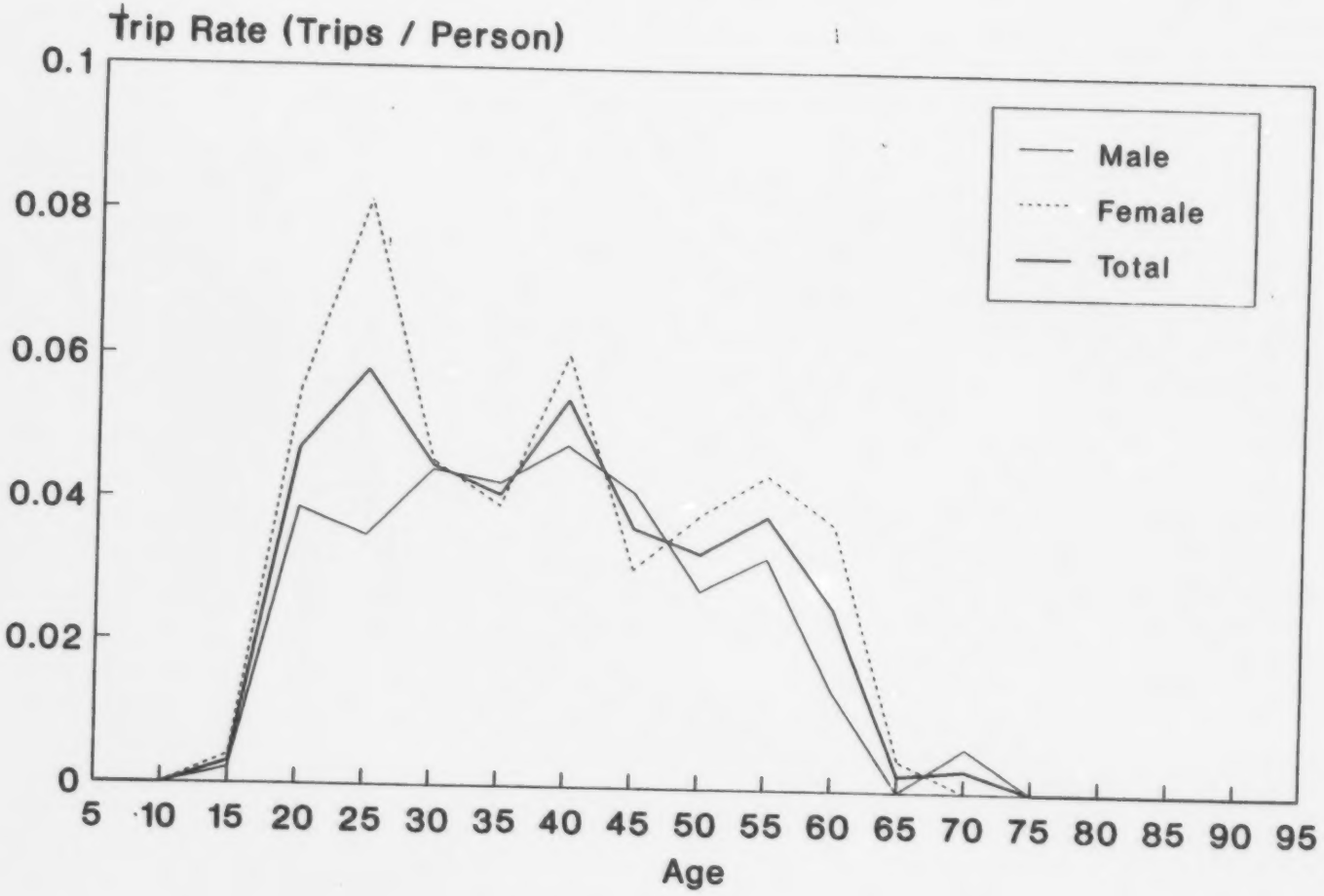
Auto Trip Rates by Age for Work Trips
for HAMILTON Region



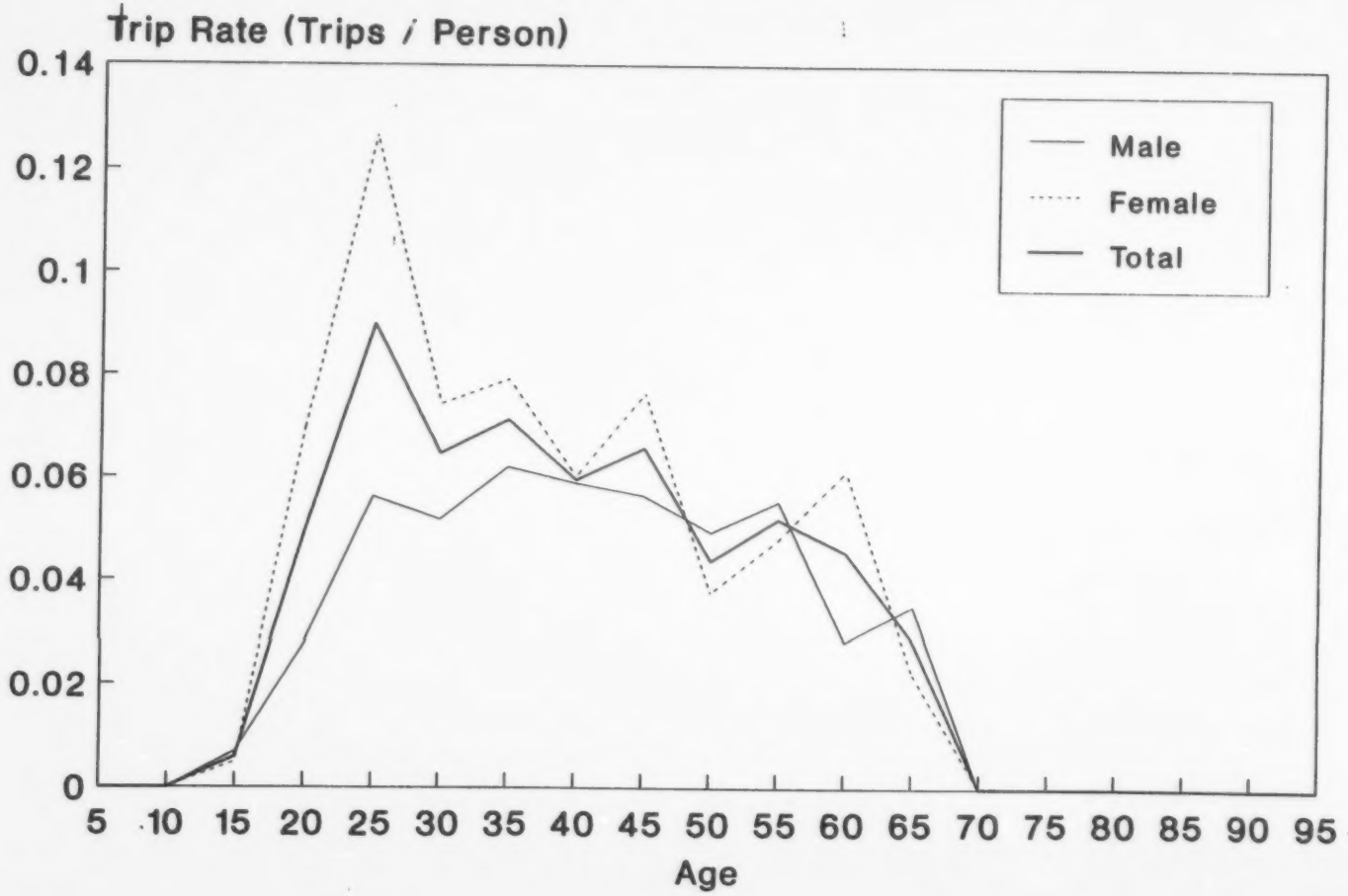
Transit Trip Rates by Age for Work Trips
for METRO Region



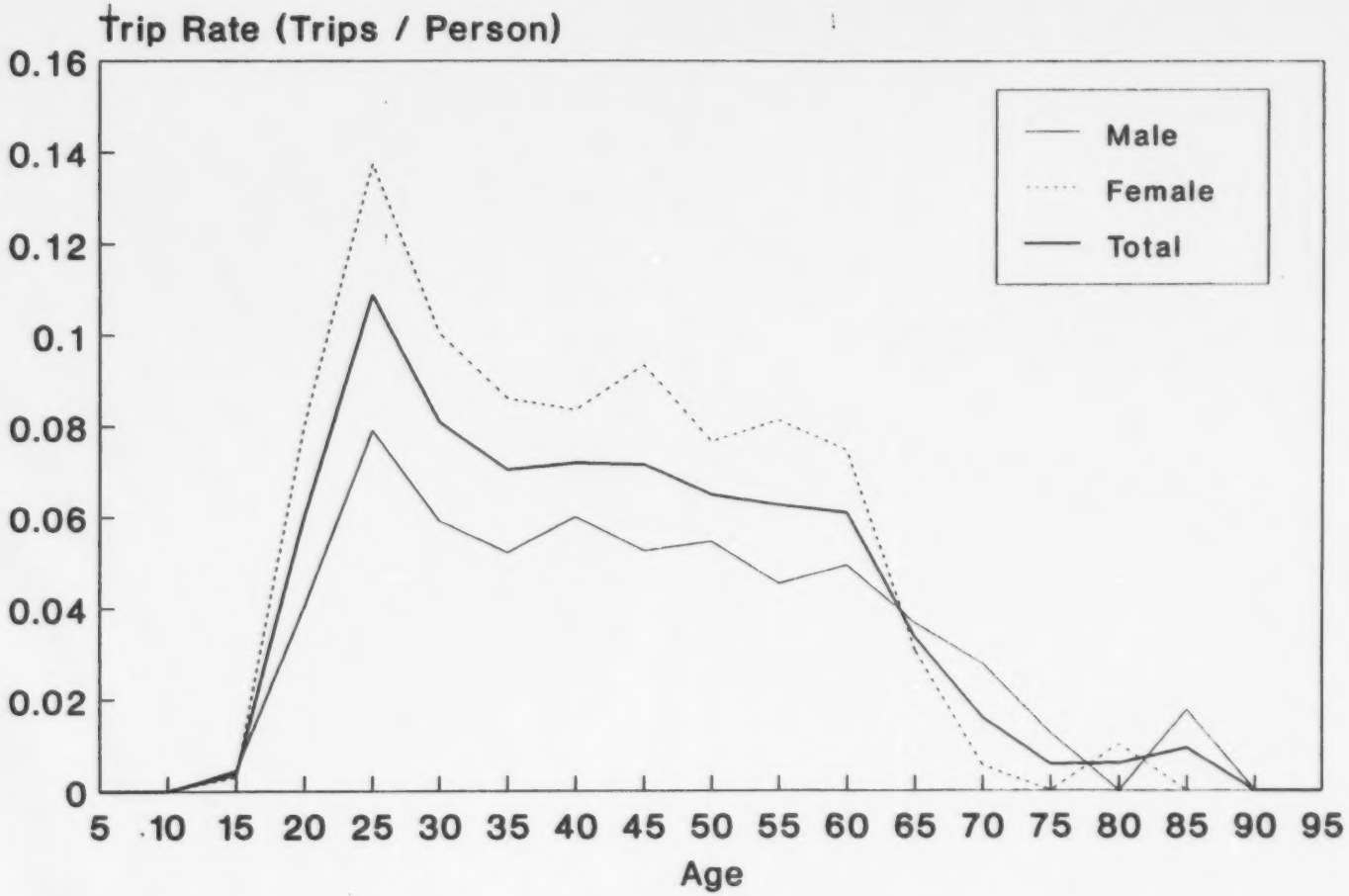
Transit Trip Rates by Age for Work Trips
for DURHAM Region



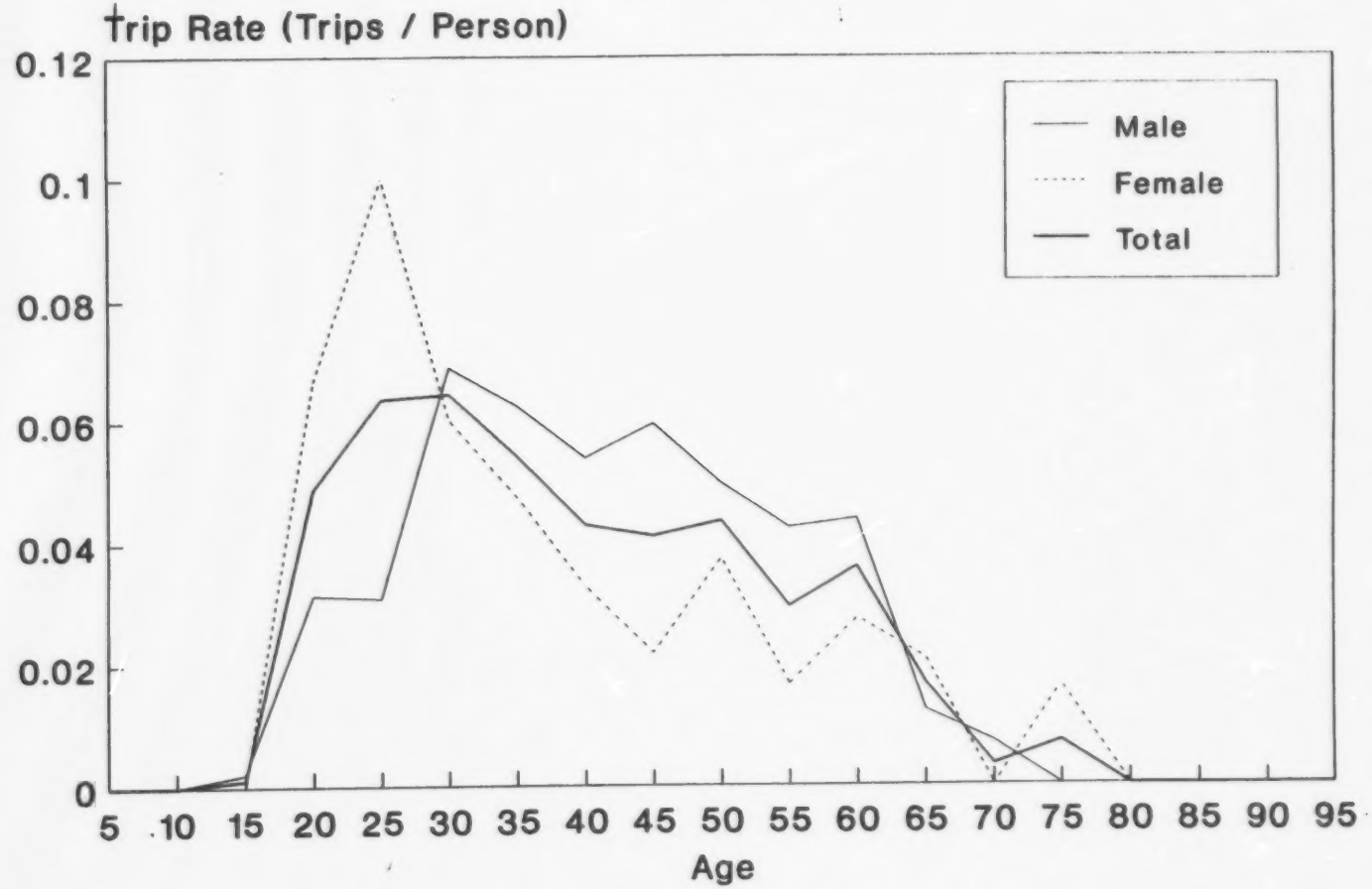
Transit Trip Rates by Age for Work Trips
for YORK Region



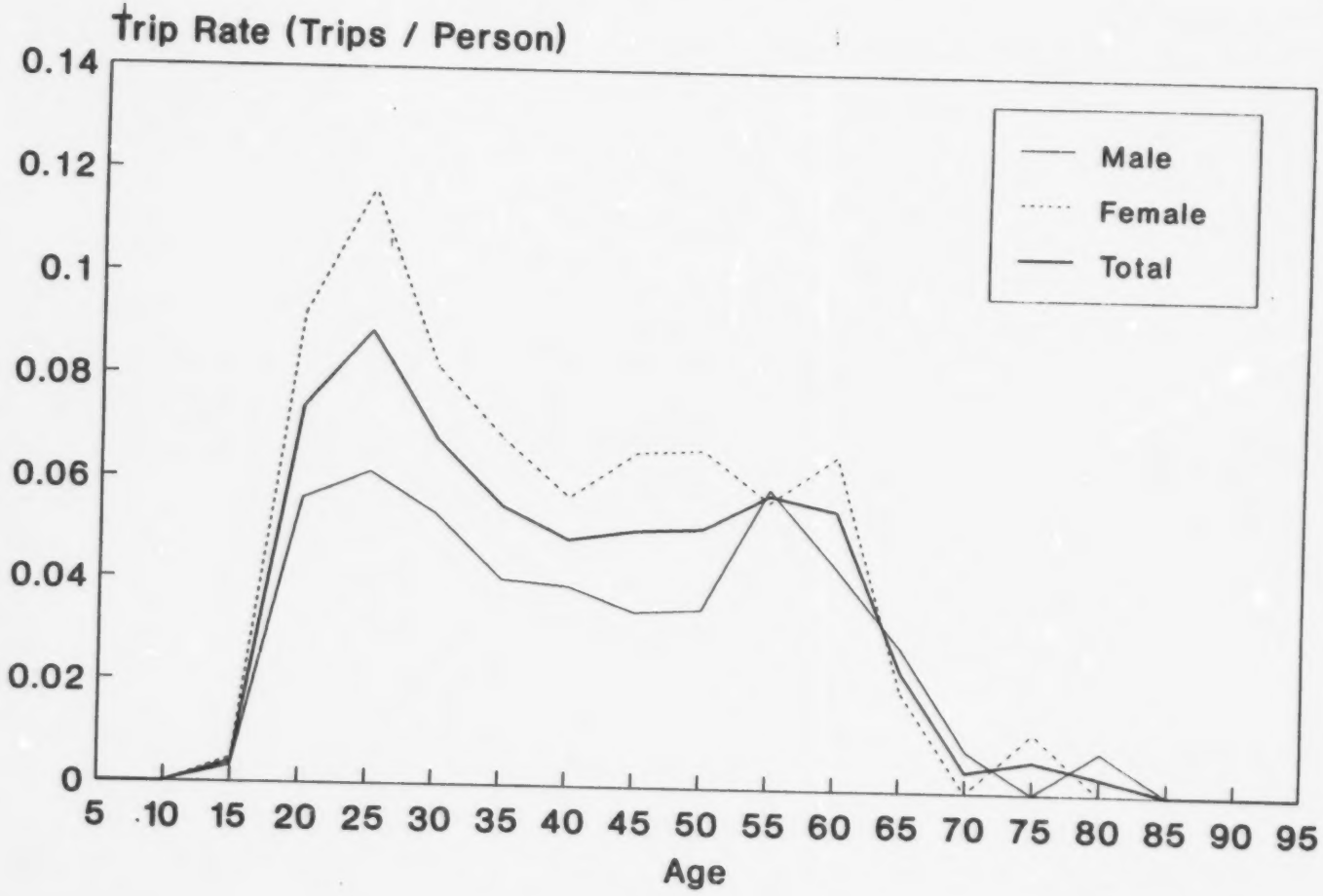
Transit Trip Rates by Age for Work Trips
for PEEL Region



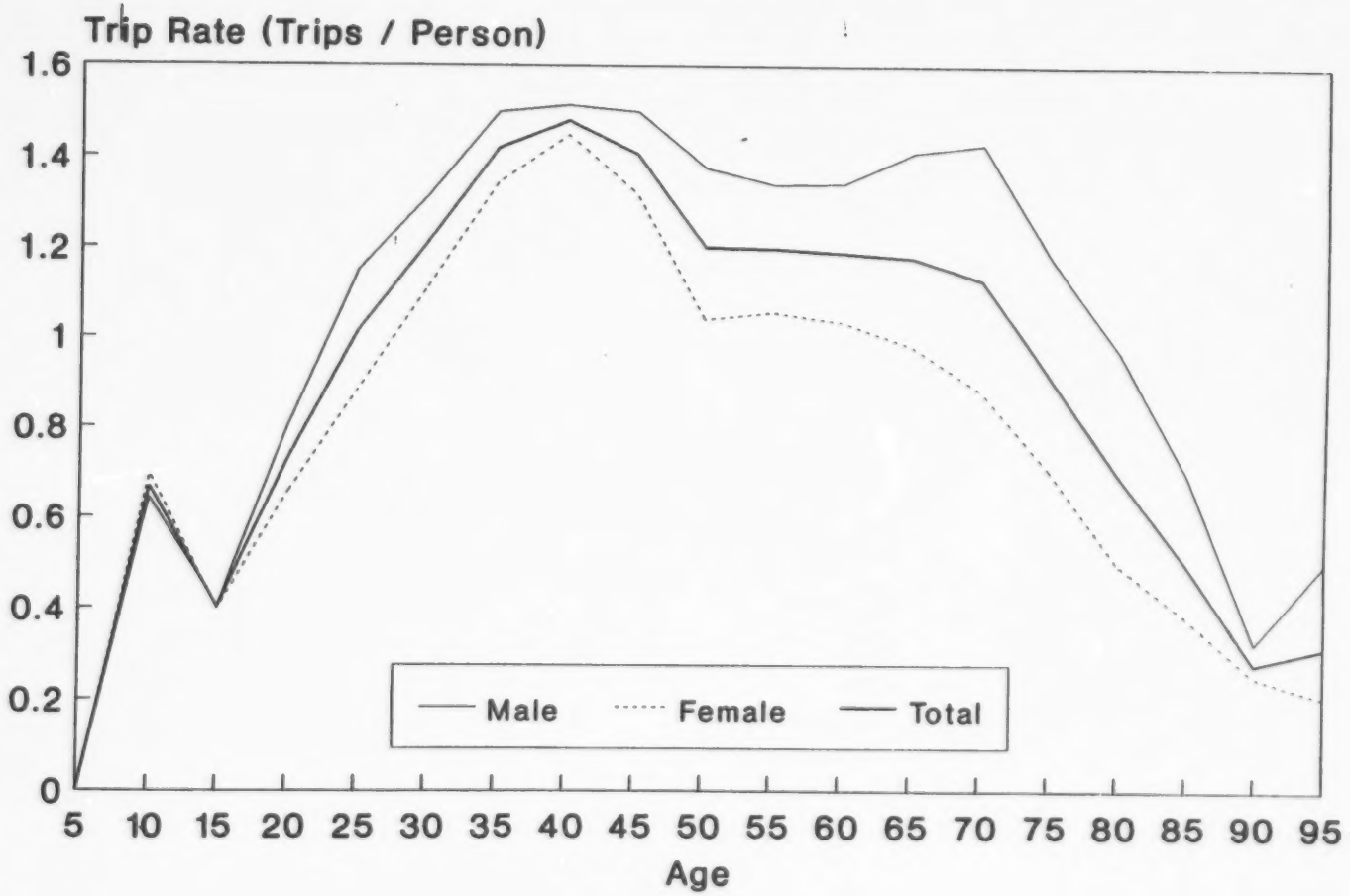
Transit Trip Rates by Age for Work Trips
for HALTON Region



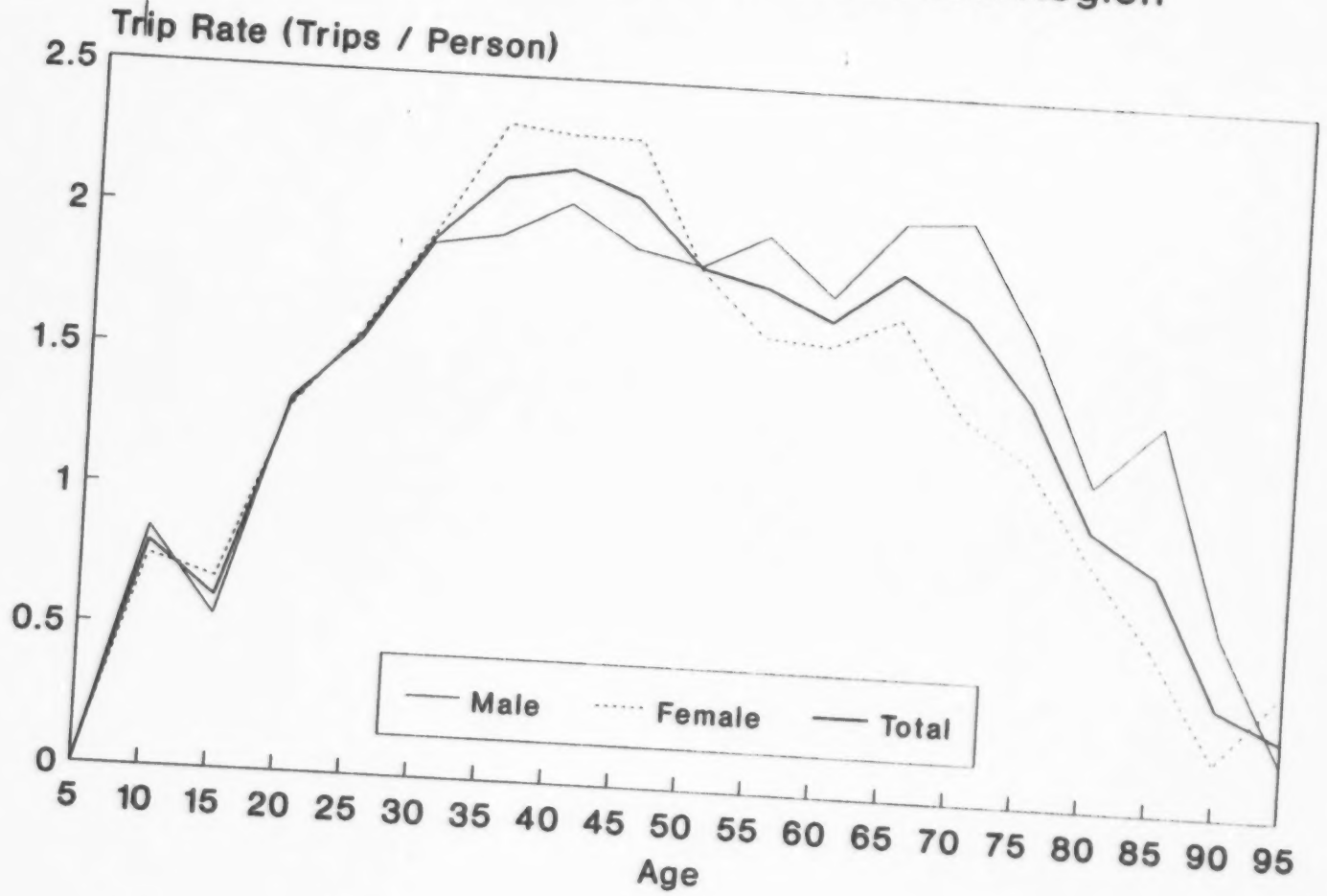
Transit Trip Rates by Age for Work Trips
for HAMILTON Region



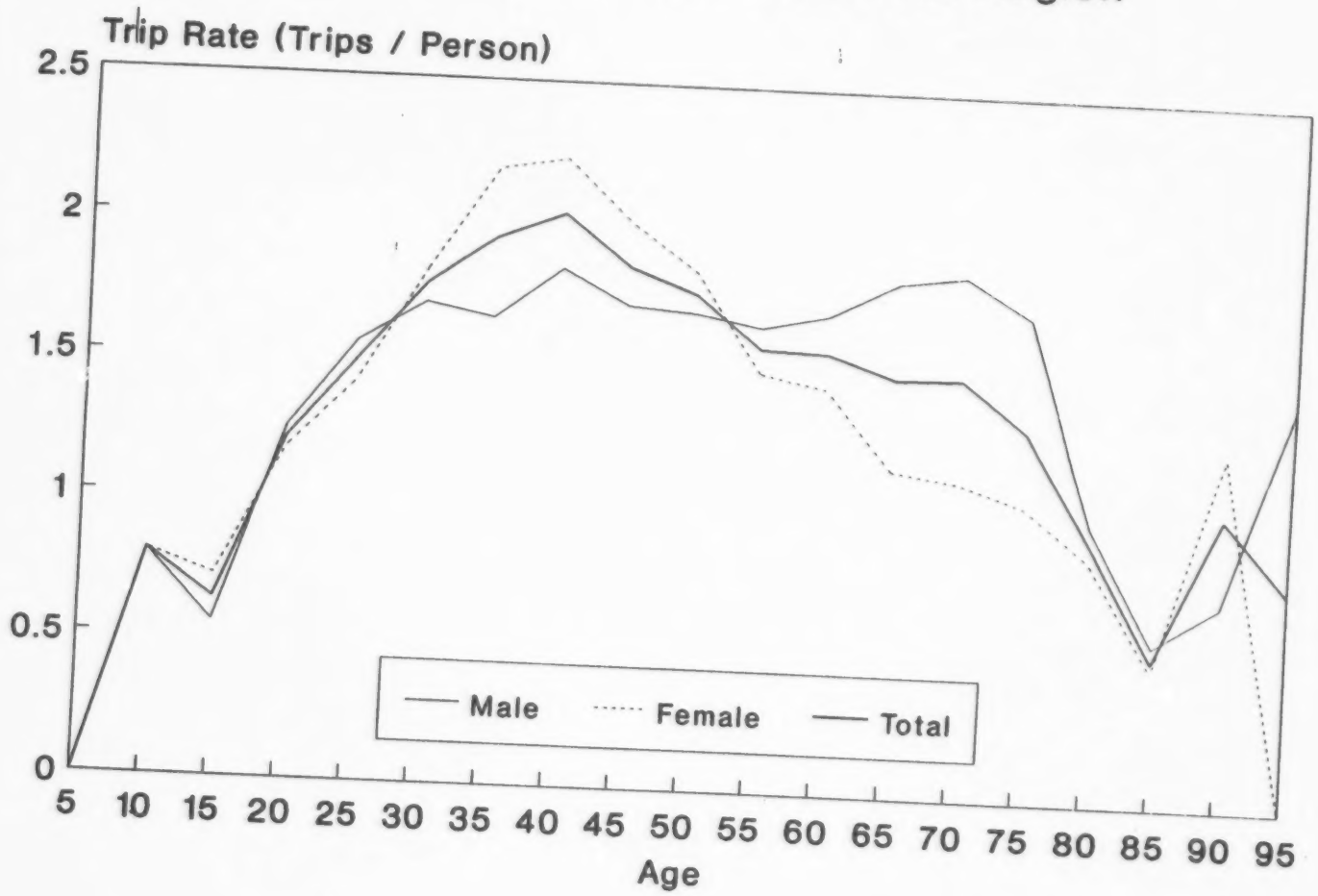
Auto Trip Rates by age
for Non-Work Trips for METRO Region



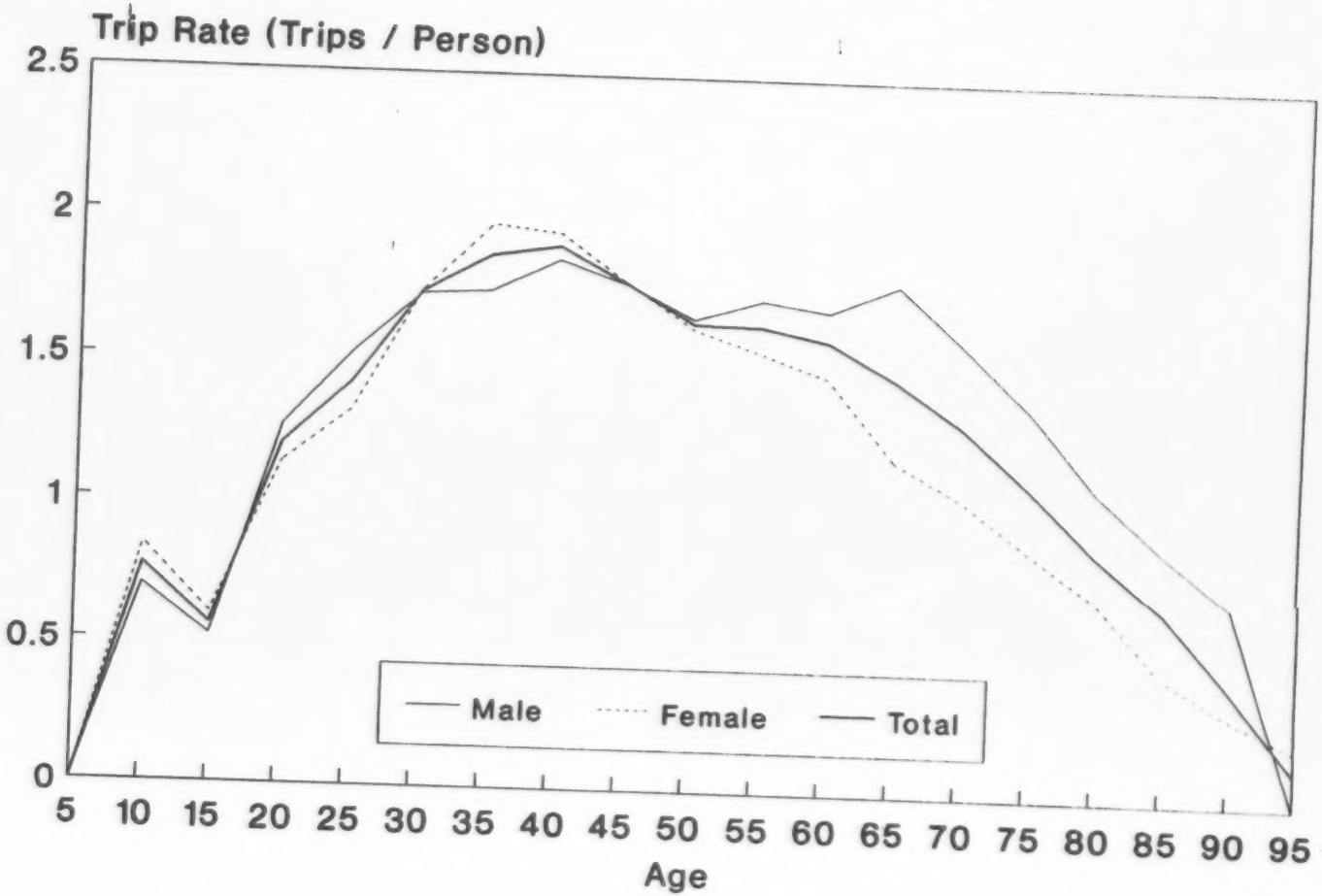
Auto Trip Rates by Age
for Non-Work Trips for DURHAM Region



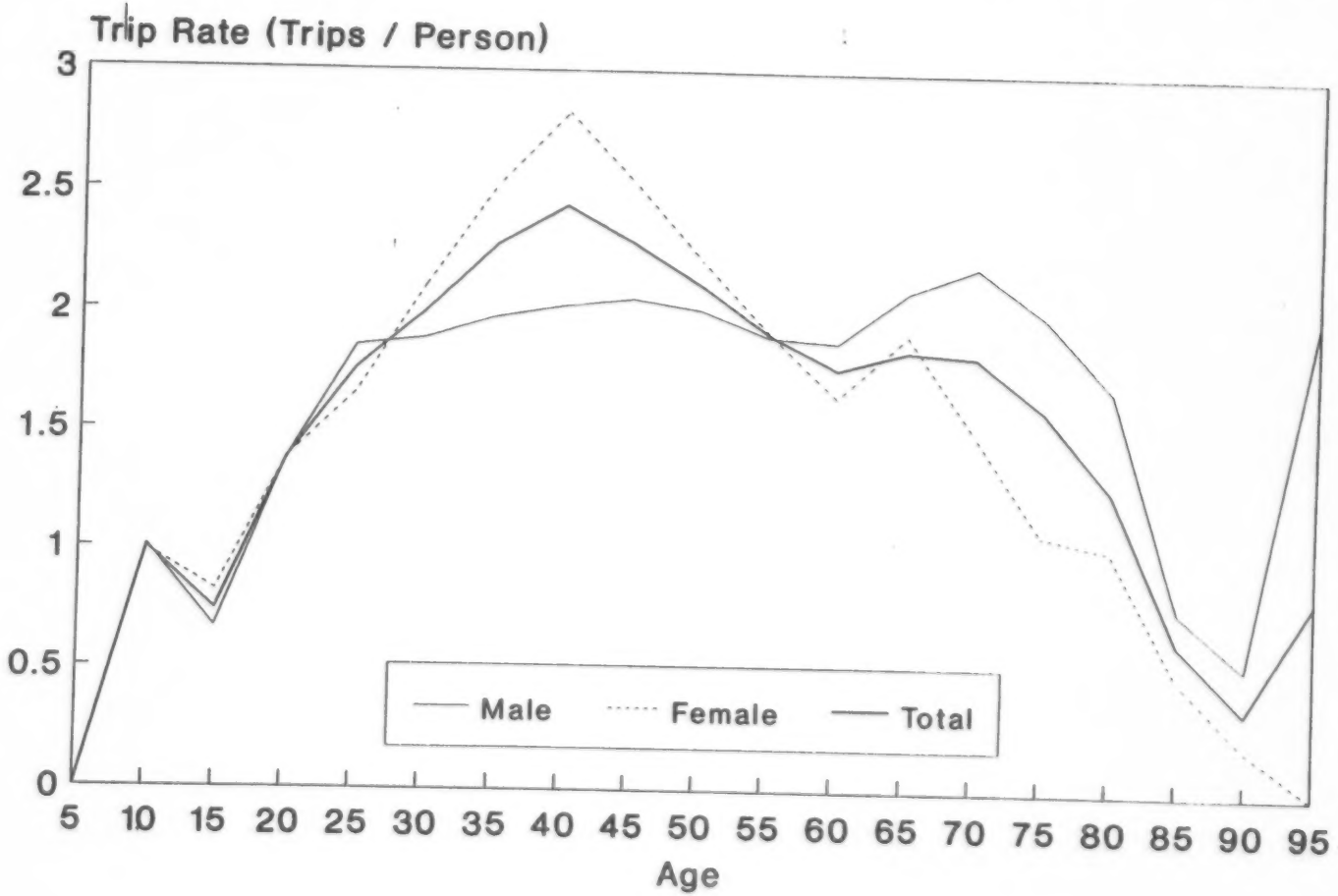
Auto Trip Rates by Age
for Non-Work Trips for YORK Region



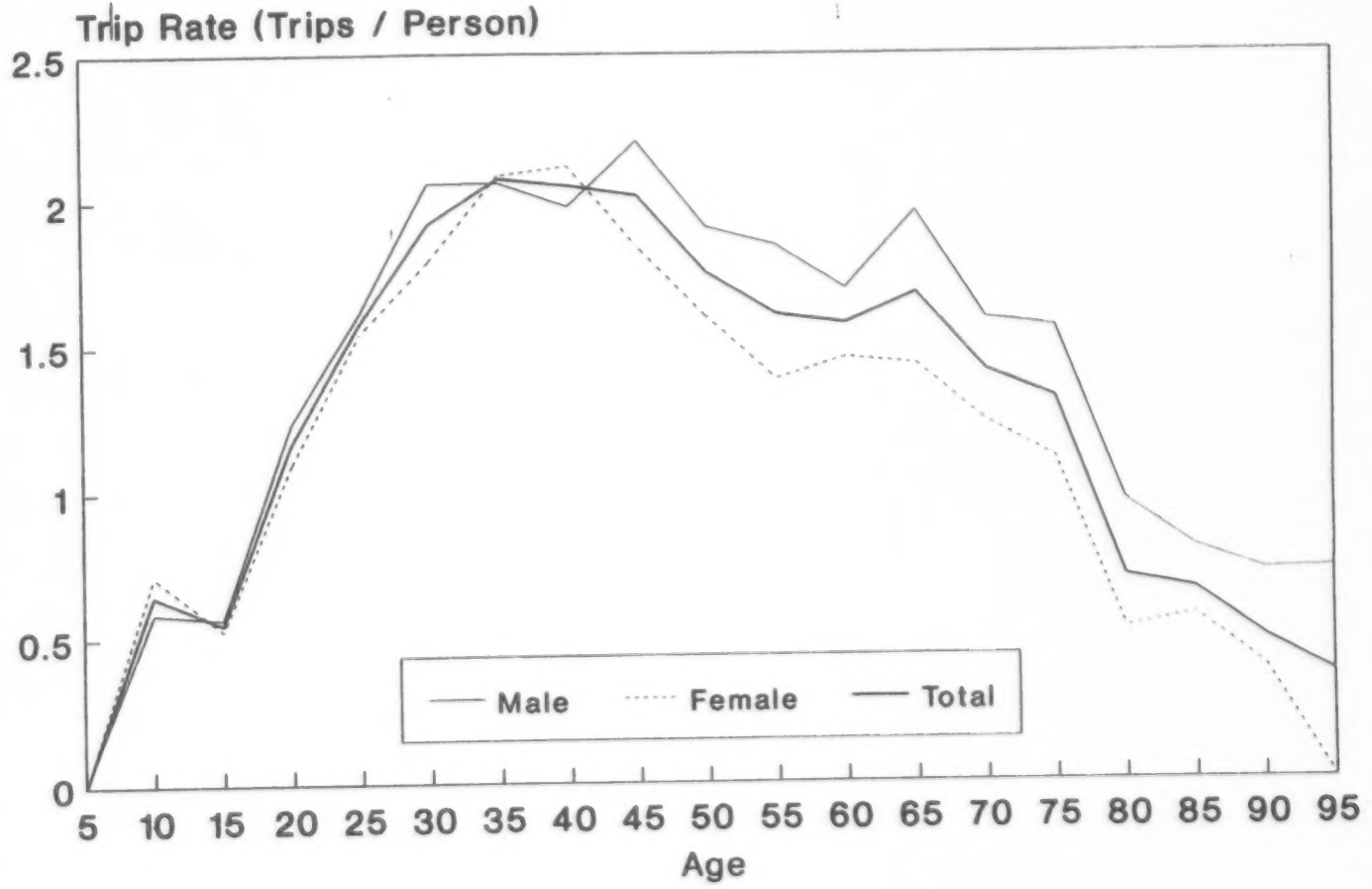
Auto Trip Rates by Age
for Non-Work Trips for PEEL Region



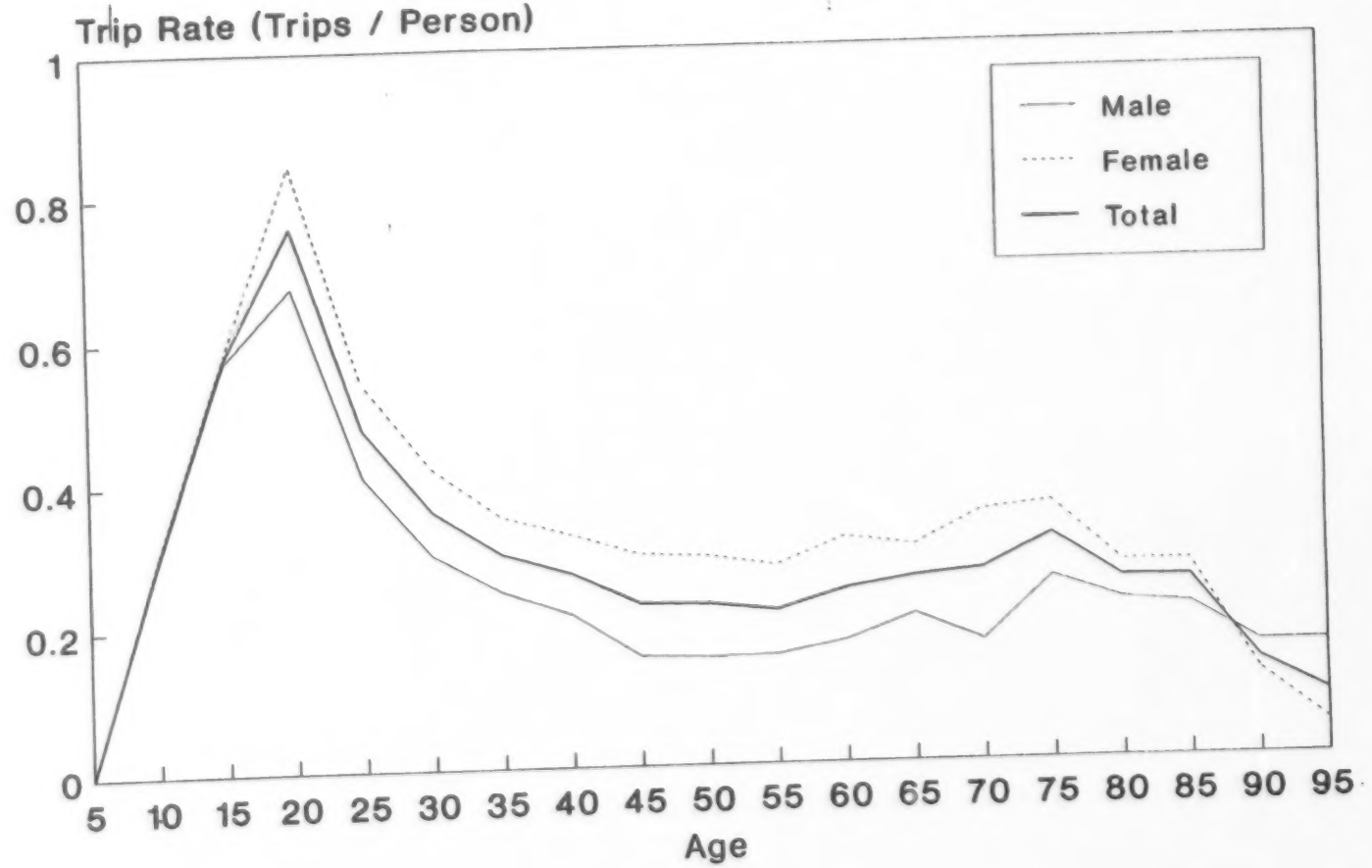
Auto Trip Rates by Age
for Non-Work Trips for HALTON Region



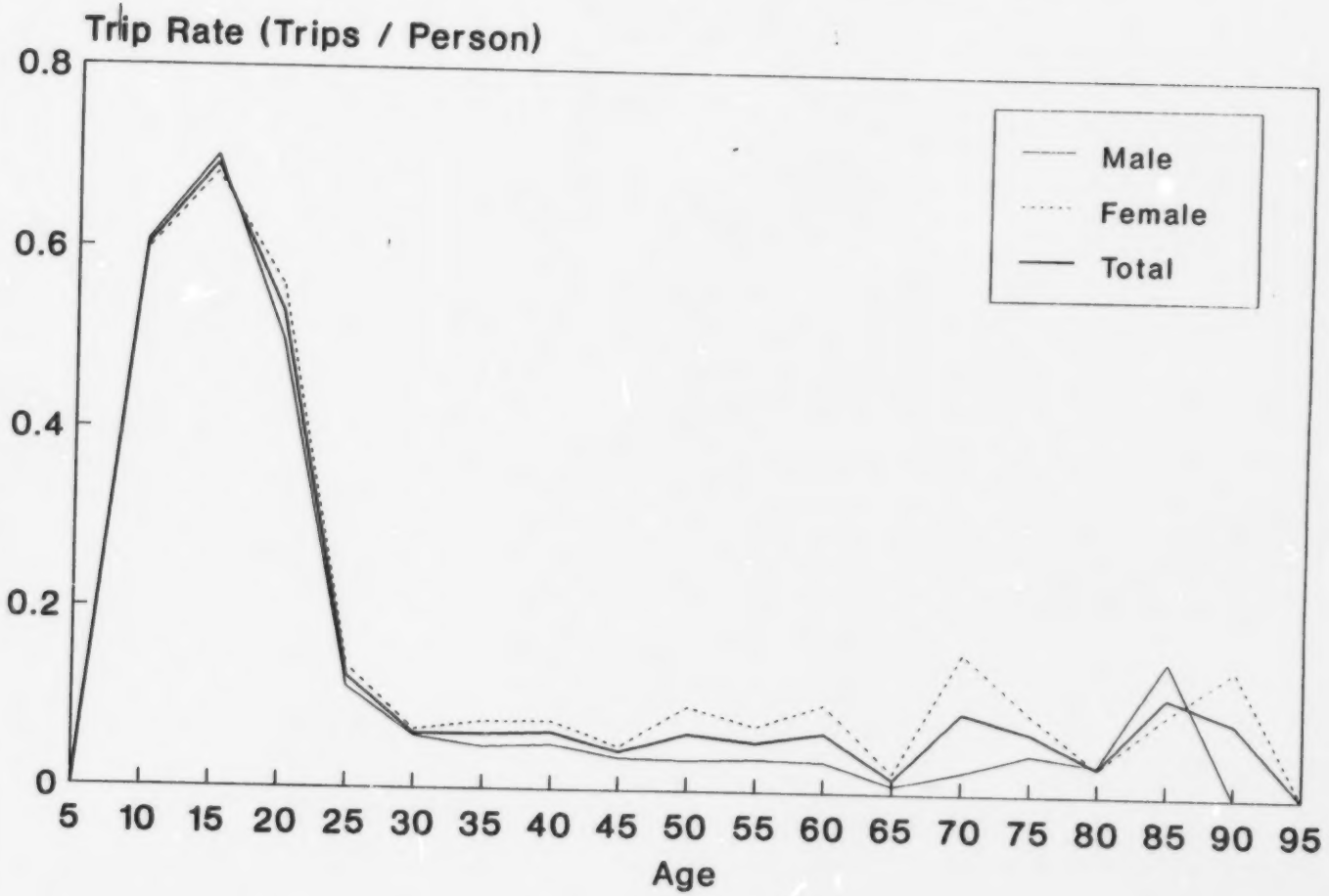
Auto Trip Rates by Age
for Non-Work Trips for HAMILTON Region



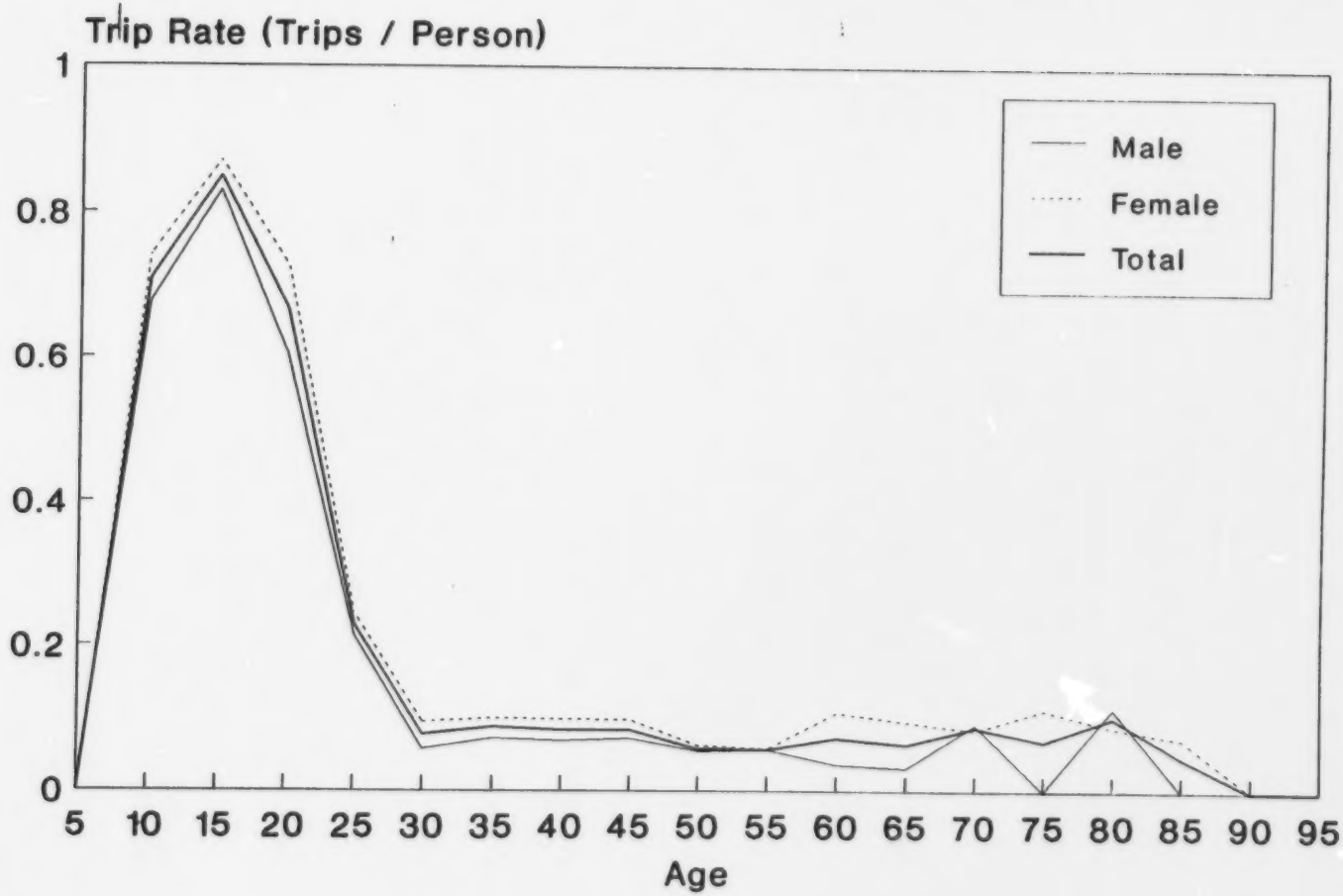
Transit Trip Rates by Age
for Non-Work Trips for METRO Region



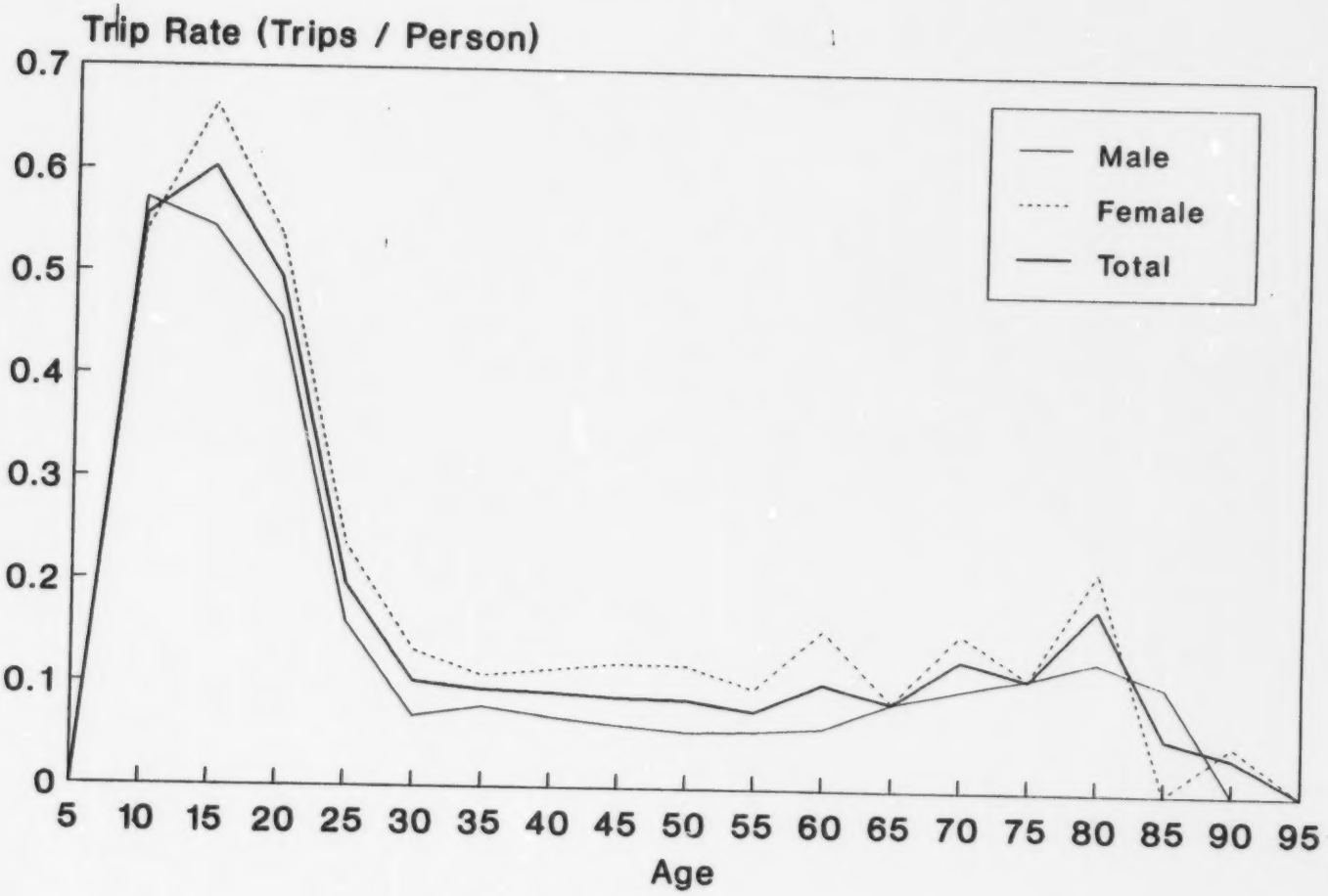
Transit Trip Rates by Age
for Non-Work Trips for DURHAM Region



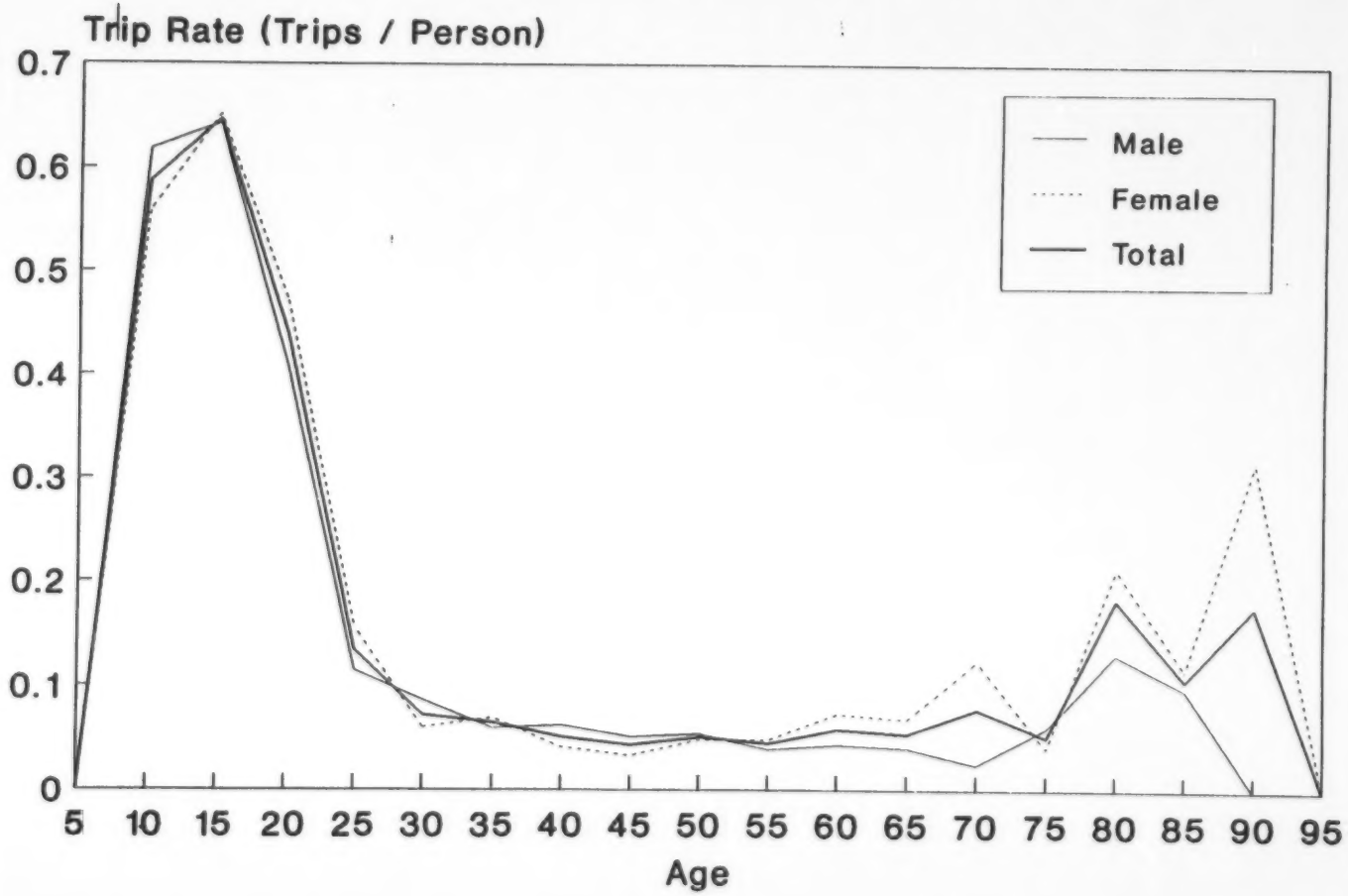
Transit Trip Rates by Age
for Non-Work Trips for YORK Region



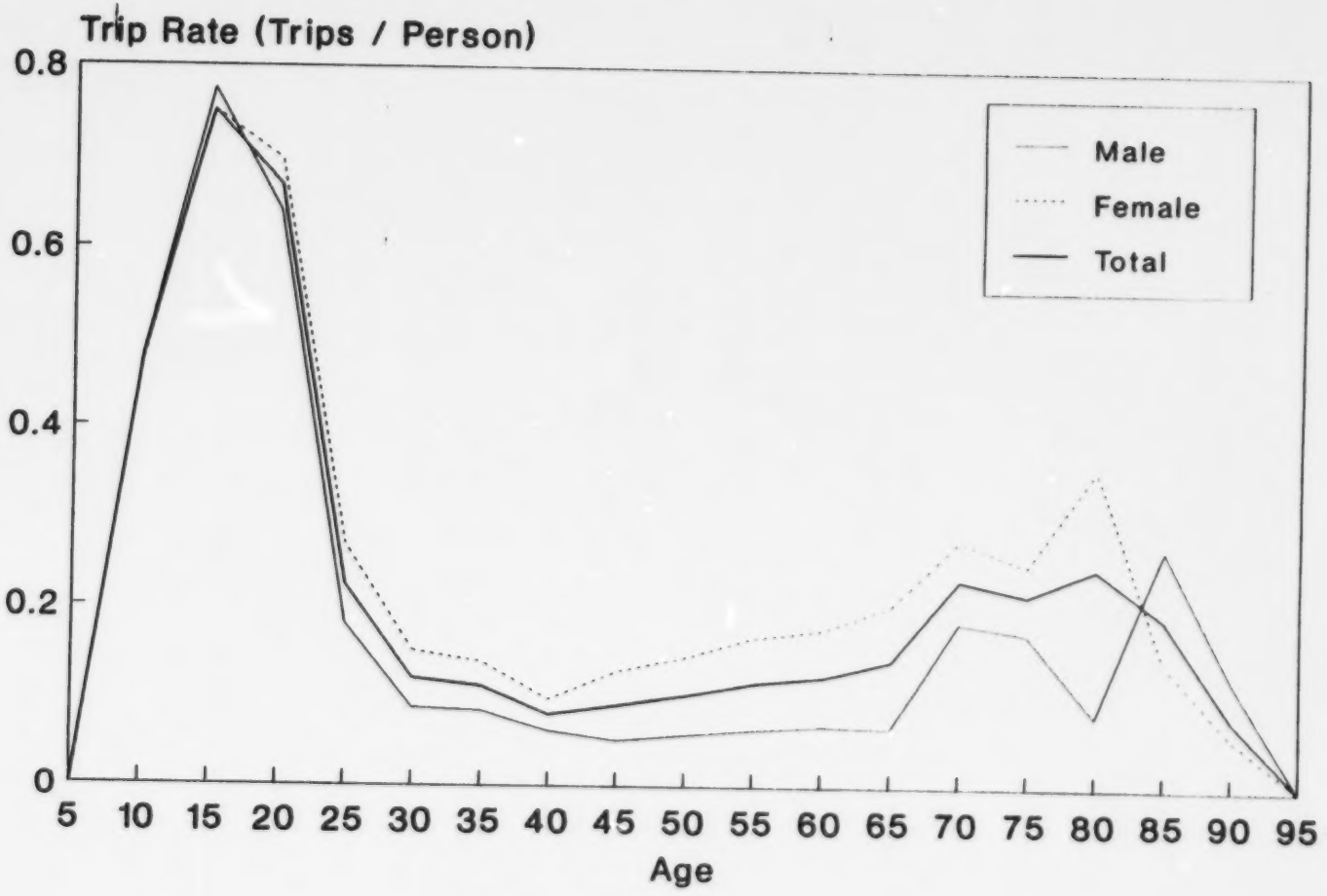
Transit Trip Rates by Age
for Non-Work Trips for PEEL Region



Transit Trip Rates by Age
for Non-Work Trips for HALTON Region



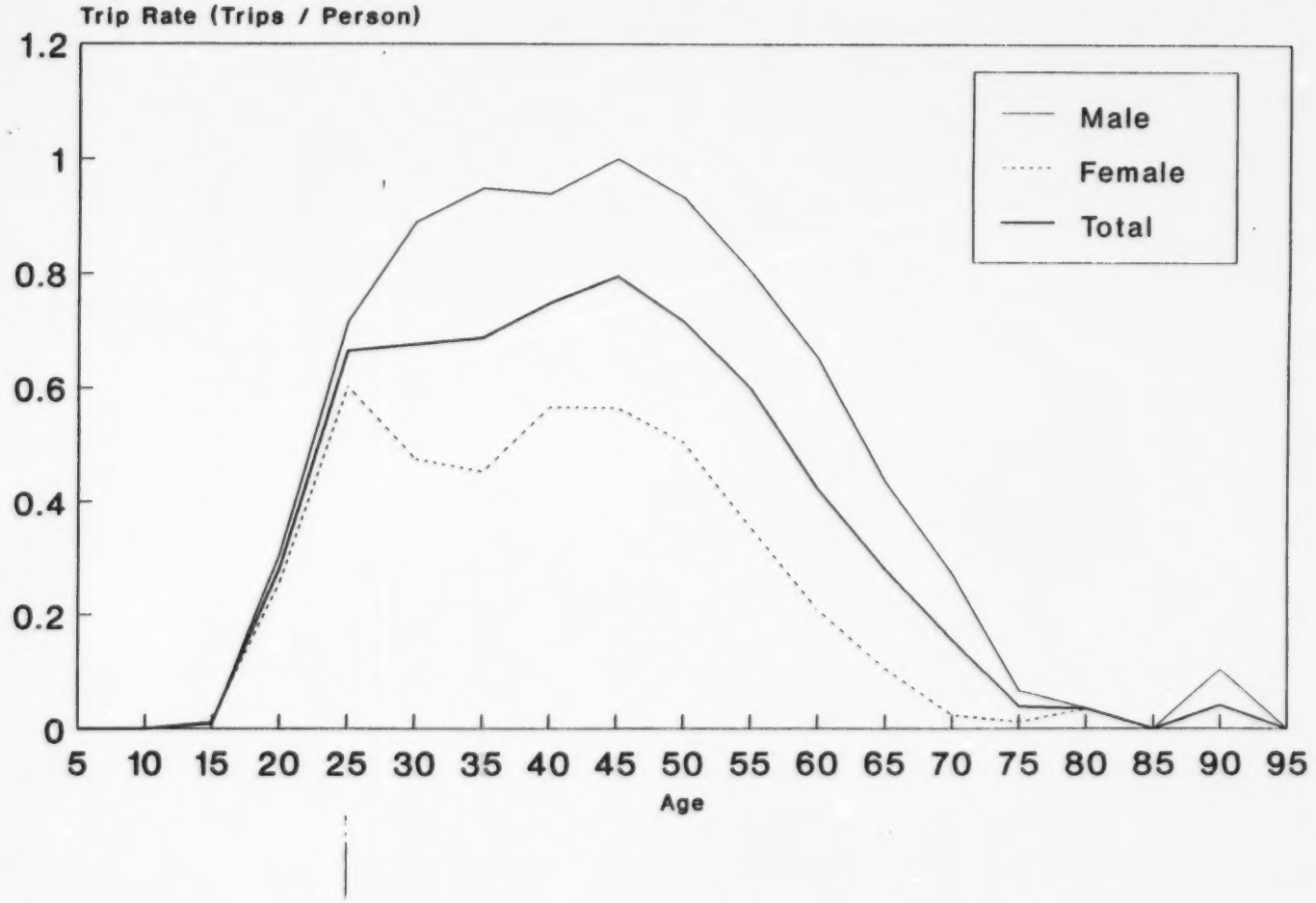
Transit Trip Rates by Age
for Non-Work Trips for HAMILTON Region



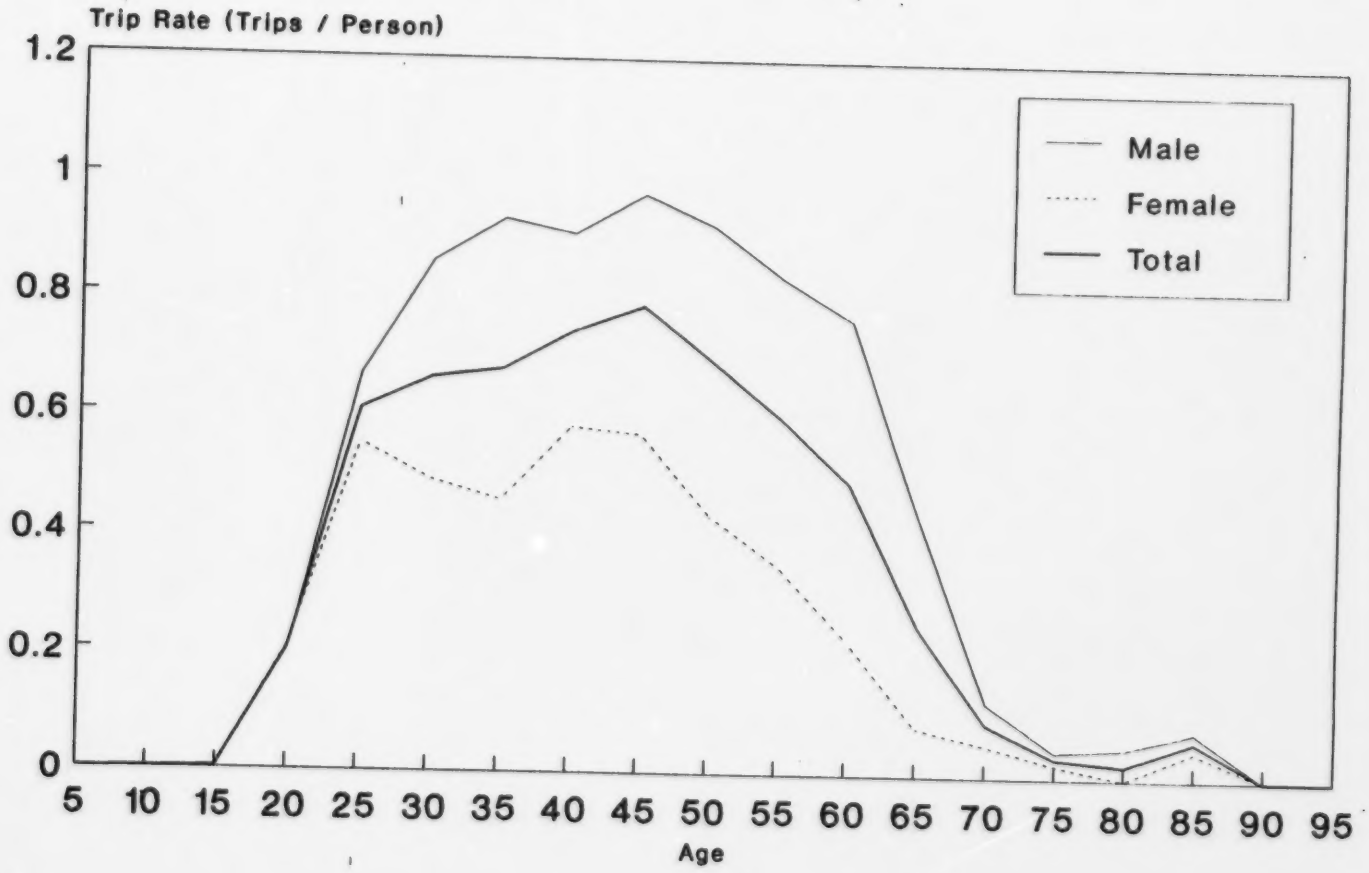
APPENDIX B

TRIP RATES BY AGE AND SEX BY TRIP PURPOSE, MODE AND URBAN DENSITY CLASS

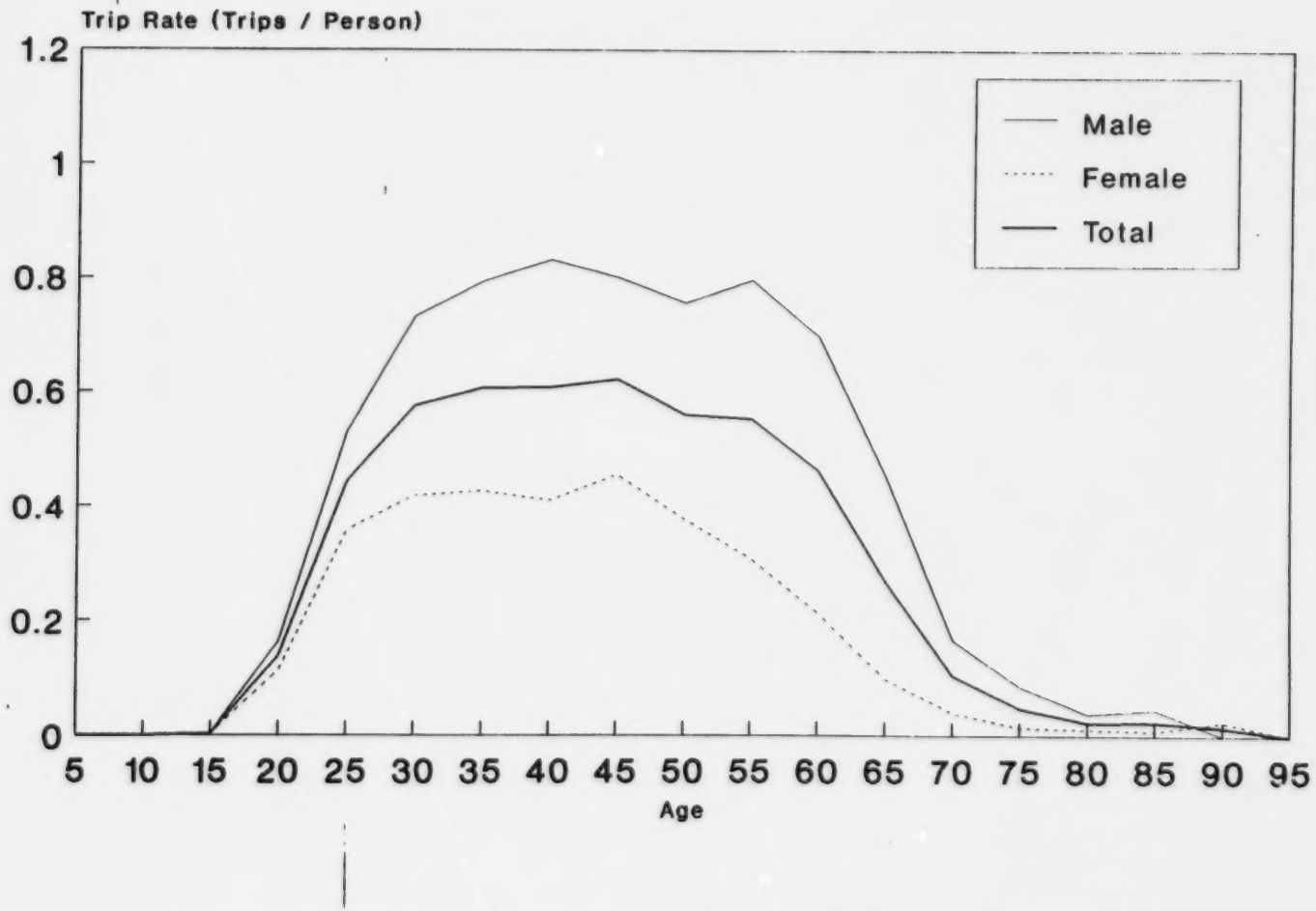
Trip Rates for Density Class 1
Auto Mode, 24 Hours
for Work Trips



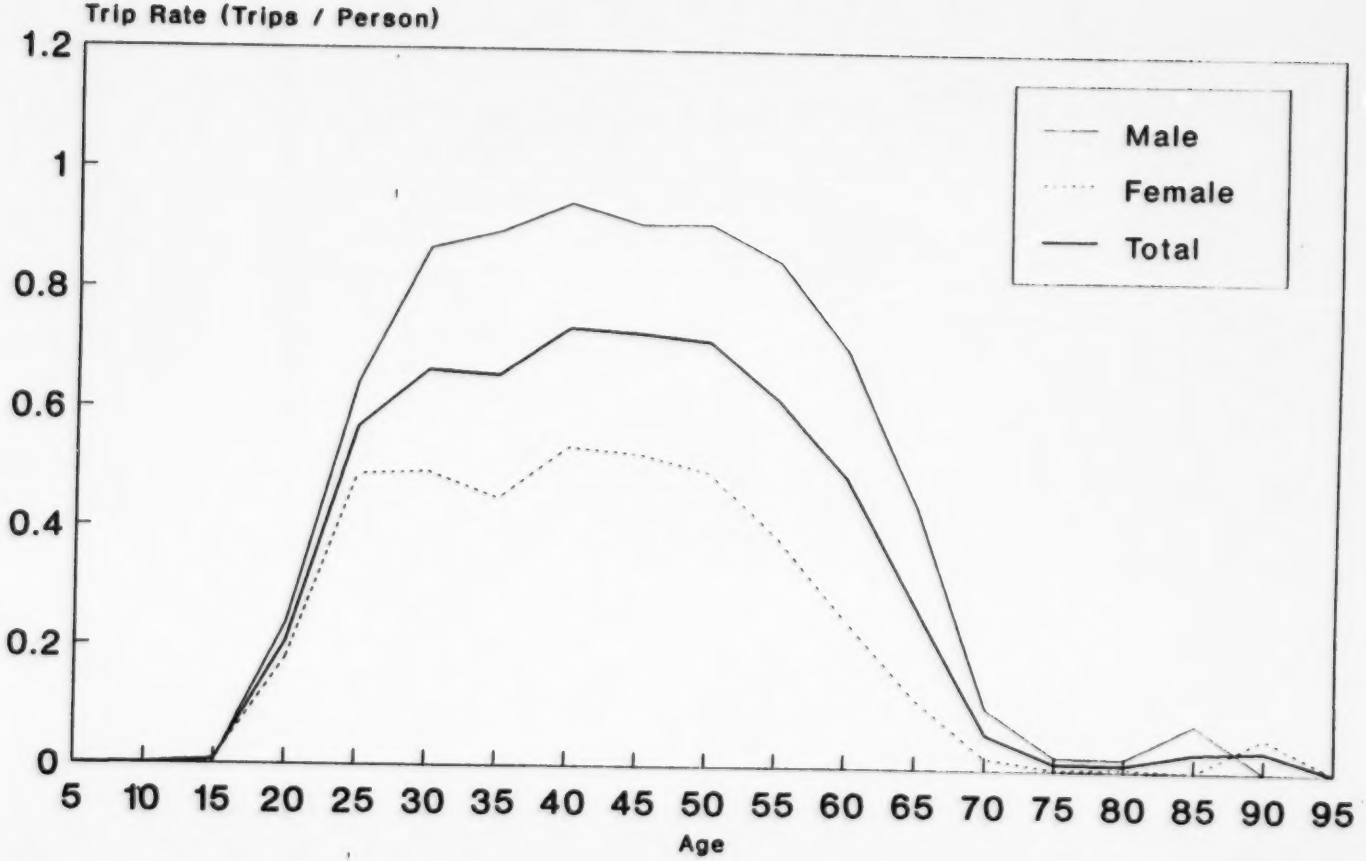
Trip Rates for Density Class 2
Auto Mode, 24 Hours
for Work Trips



Trips Rates for Density Class 3 (Metro)
Auto Mode, 24 Hours
for Work Trips

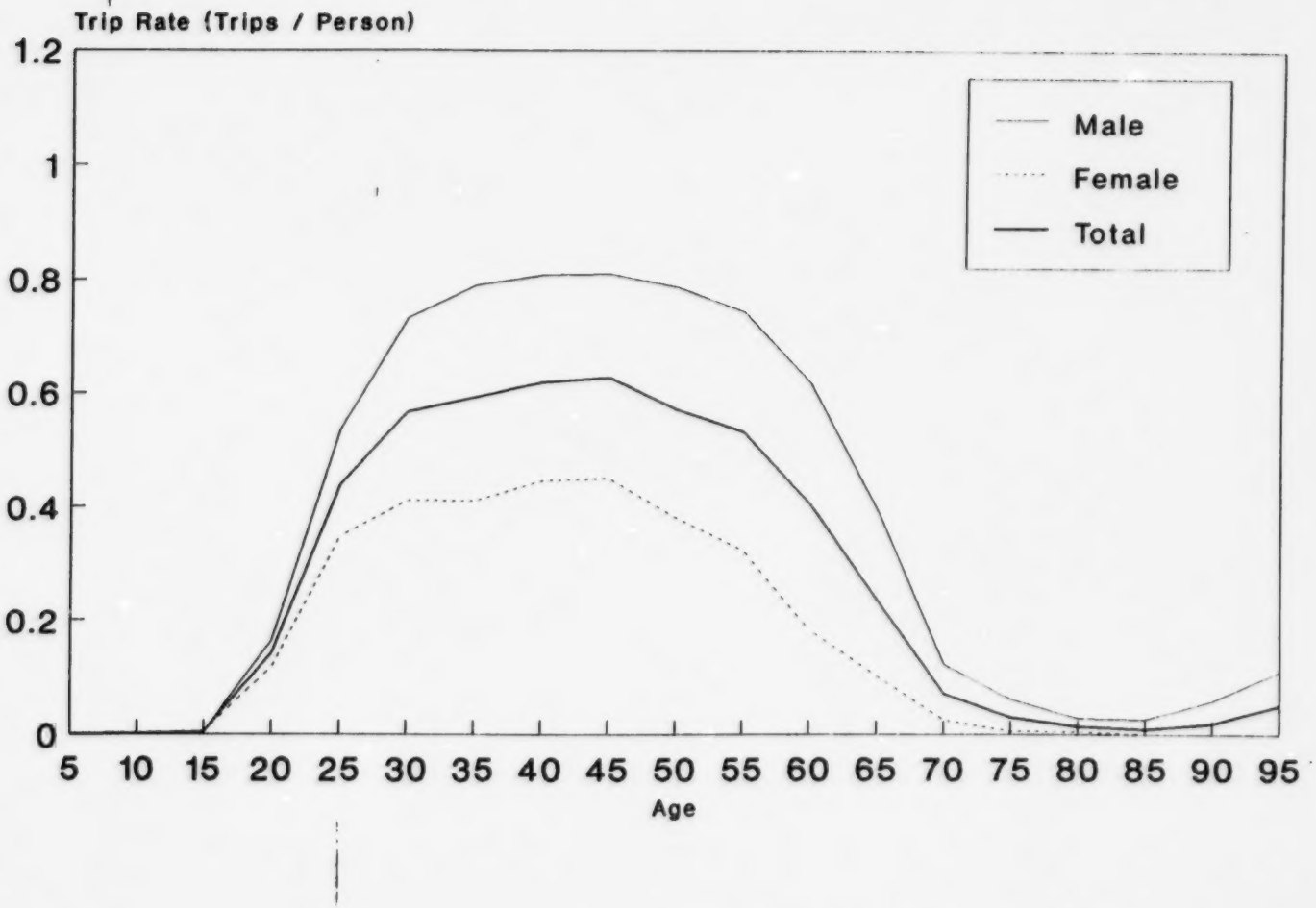


Trip Rates for Density Class 3 (Other)
Auto Mode, 24 Hours
for Work Trips

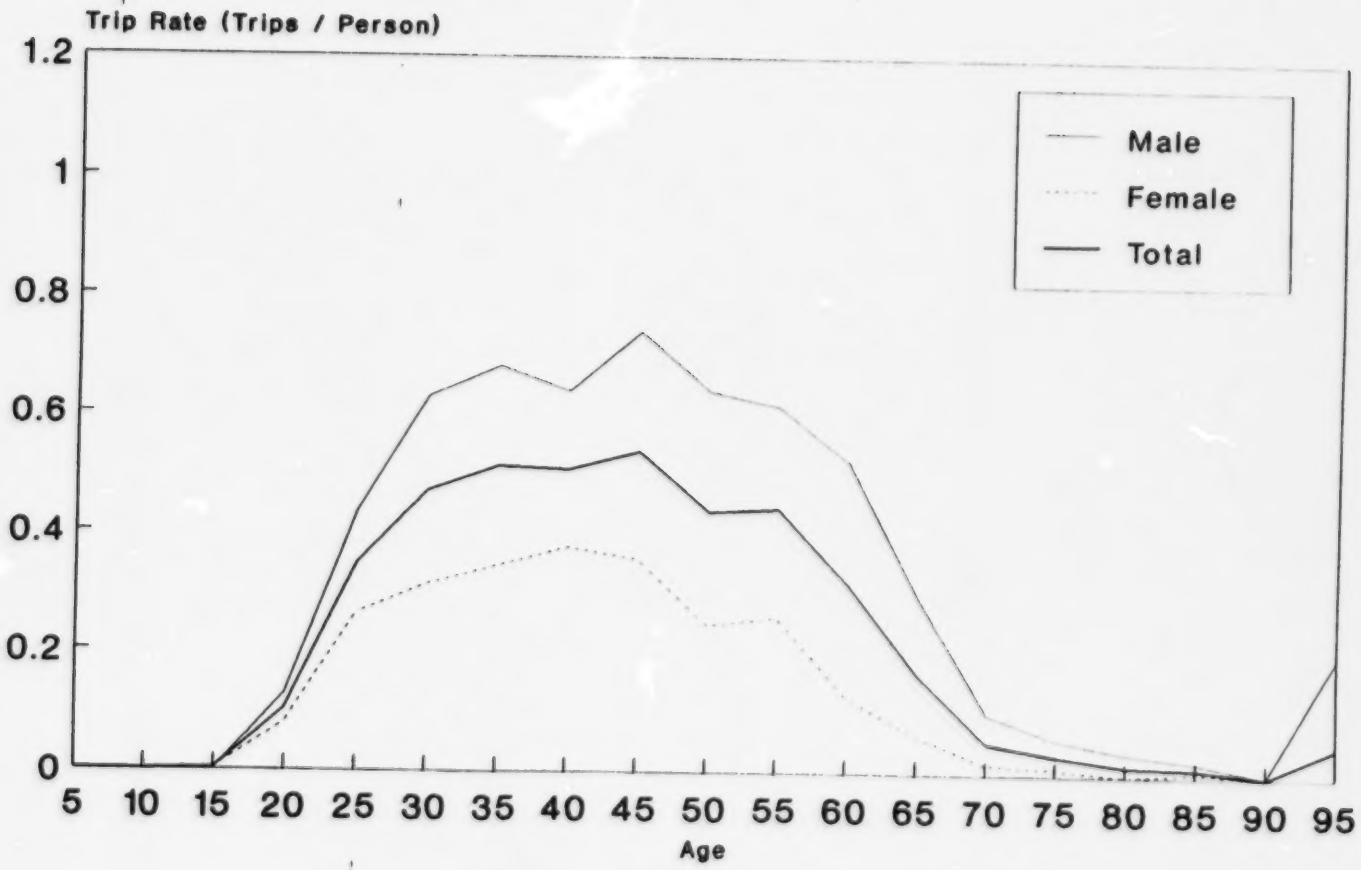


B4

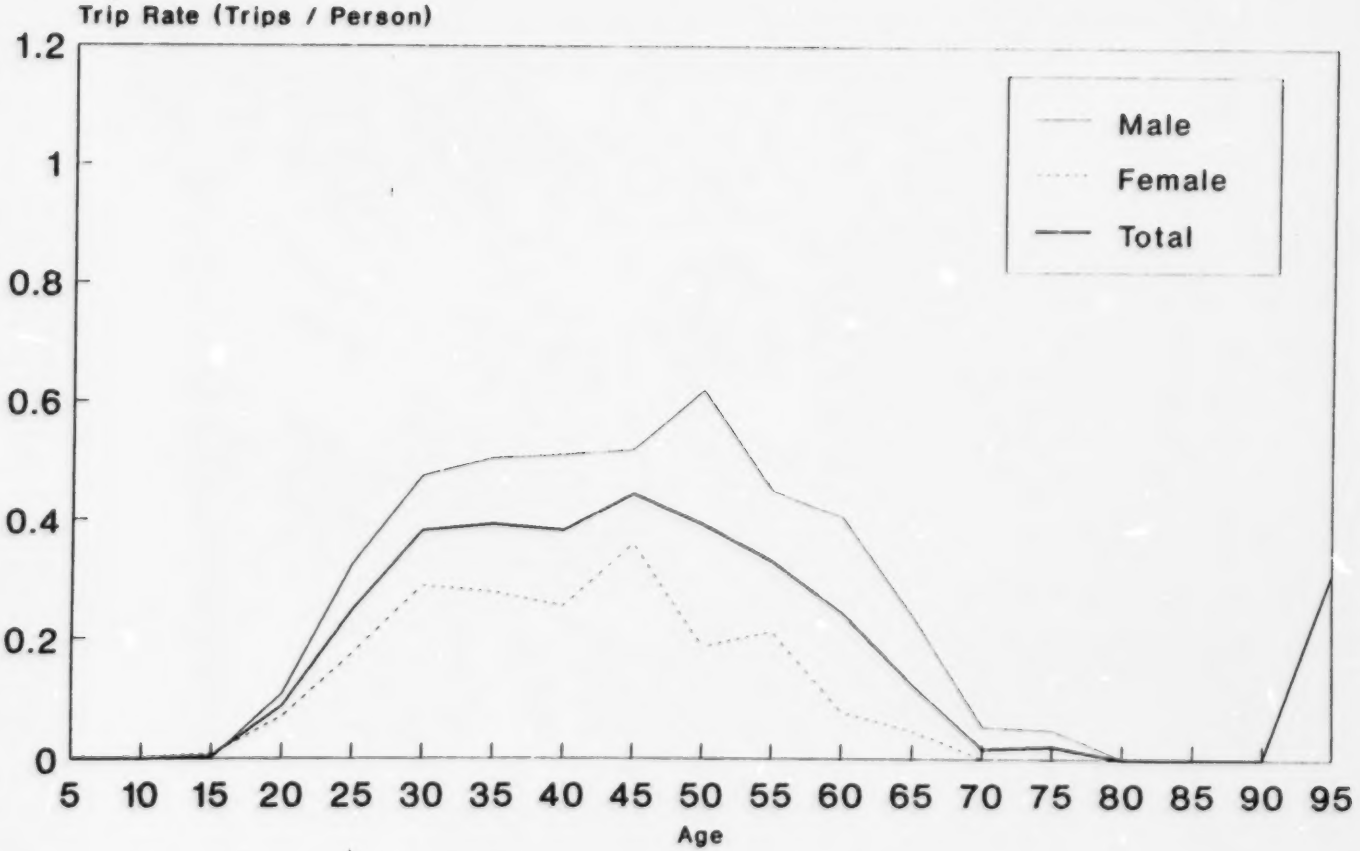
Trip Rates for Density Class 4
Auto Mode, 24 Hours
for Work Trips



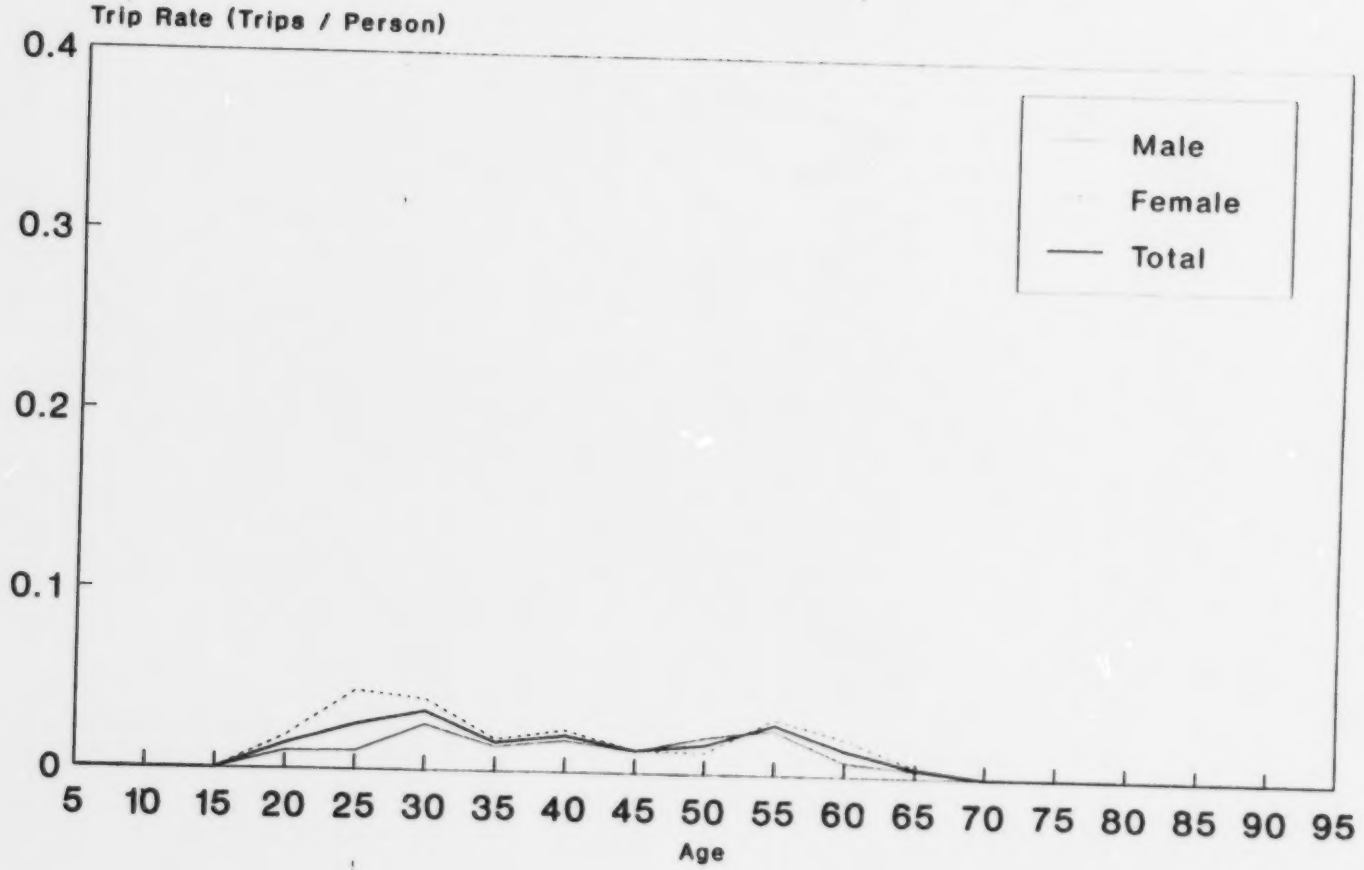
Trip Rates for Density Class 5
Auto Mode, 24 Hours
for Work Trips



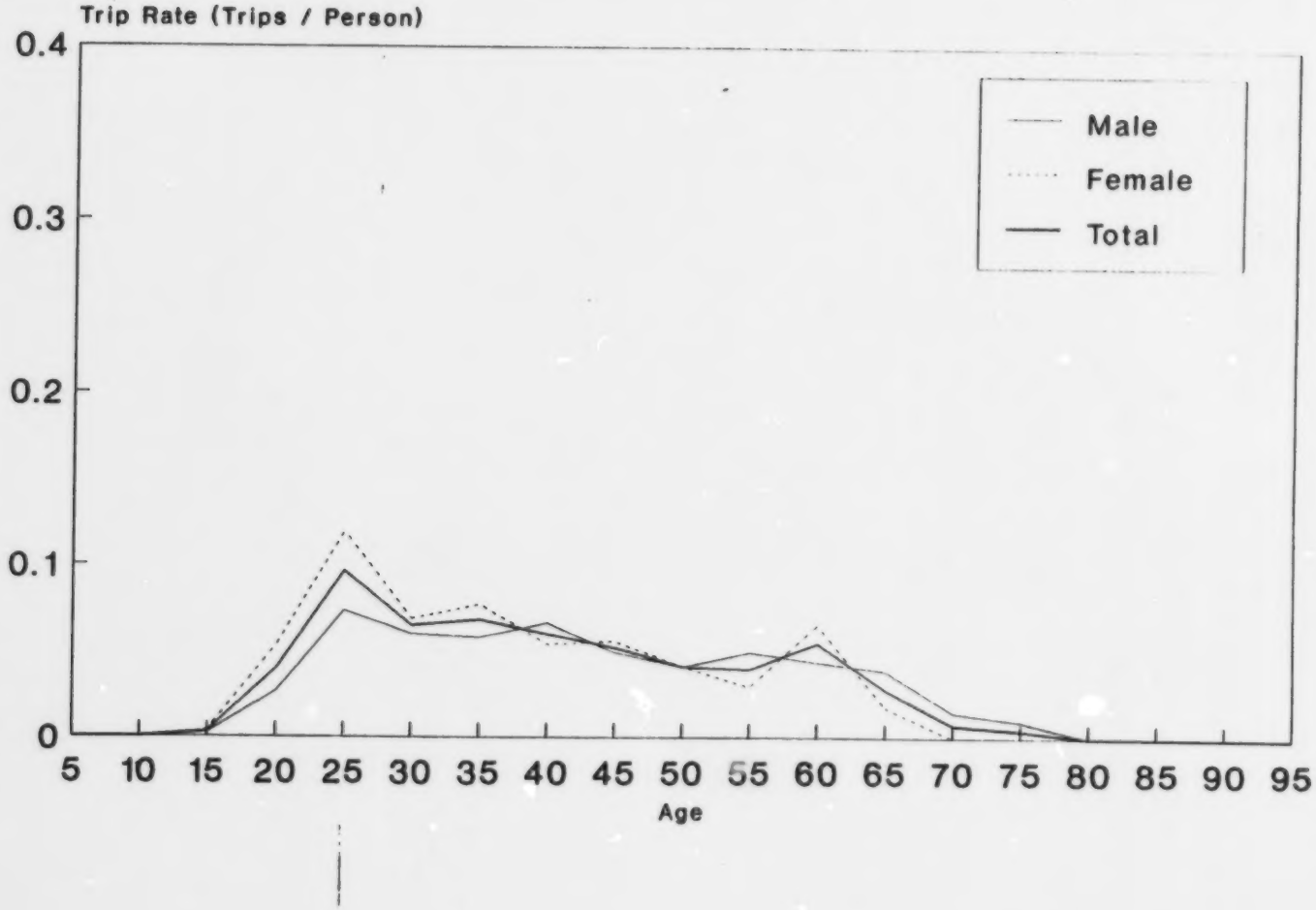
Trip Rates for Density Class 6
Auto Mode, 24 Hours
for Work Trips



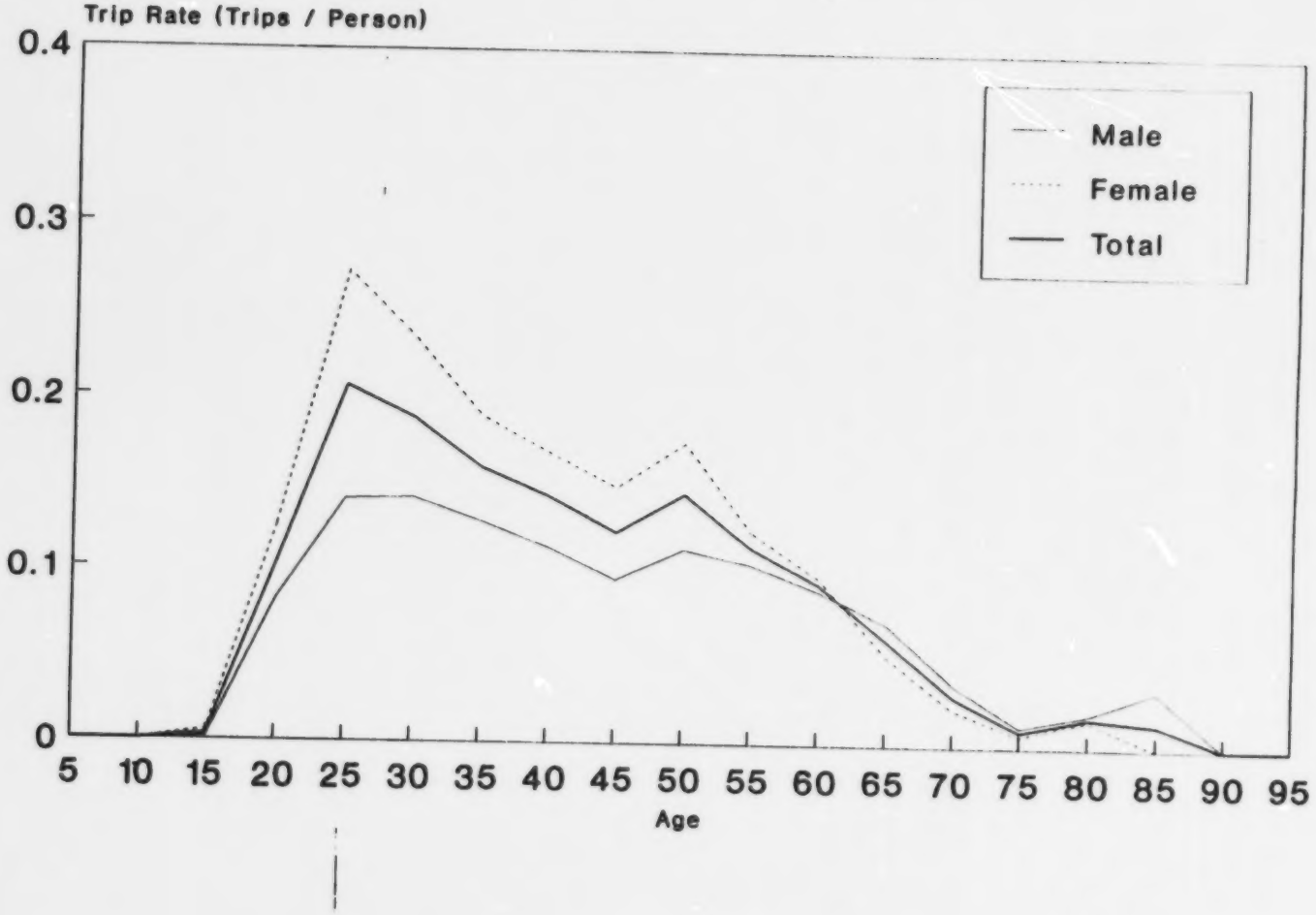
Trip Rates for Density Class 1
Transit Mode, 24 Hours
for Work Trips



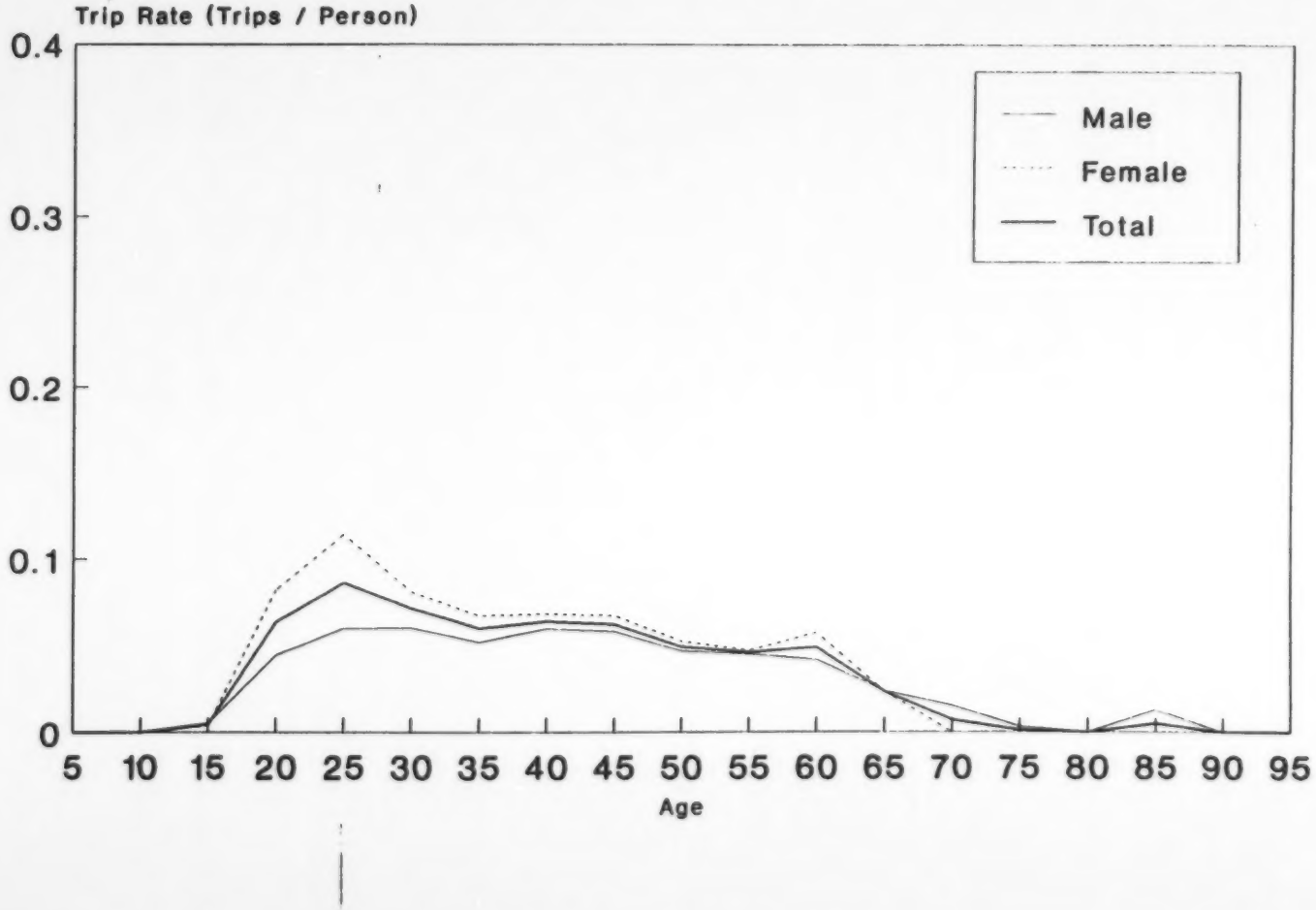
Trip Rates for Density Class 2
Transit Mode, 24 Hours
for Work Trips



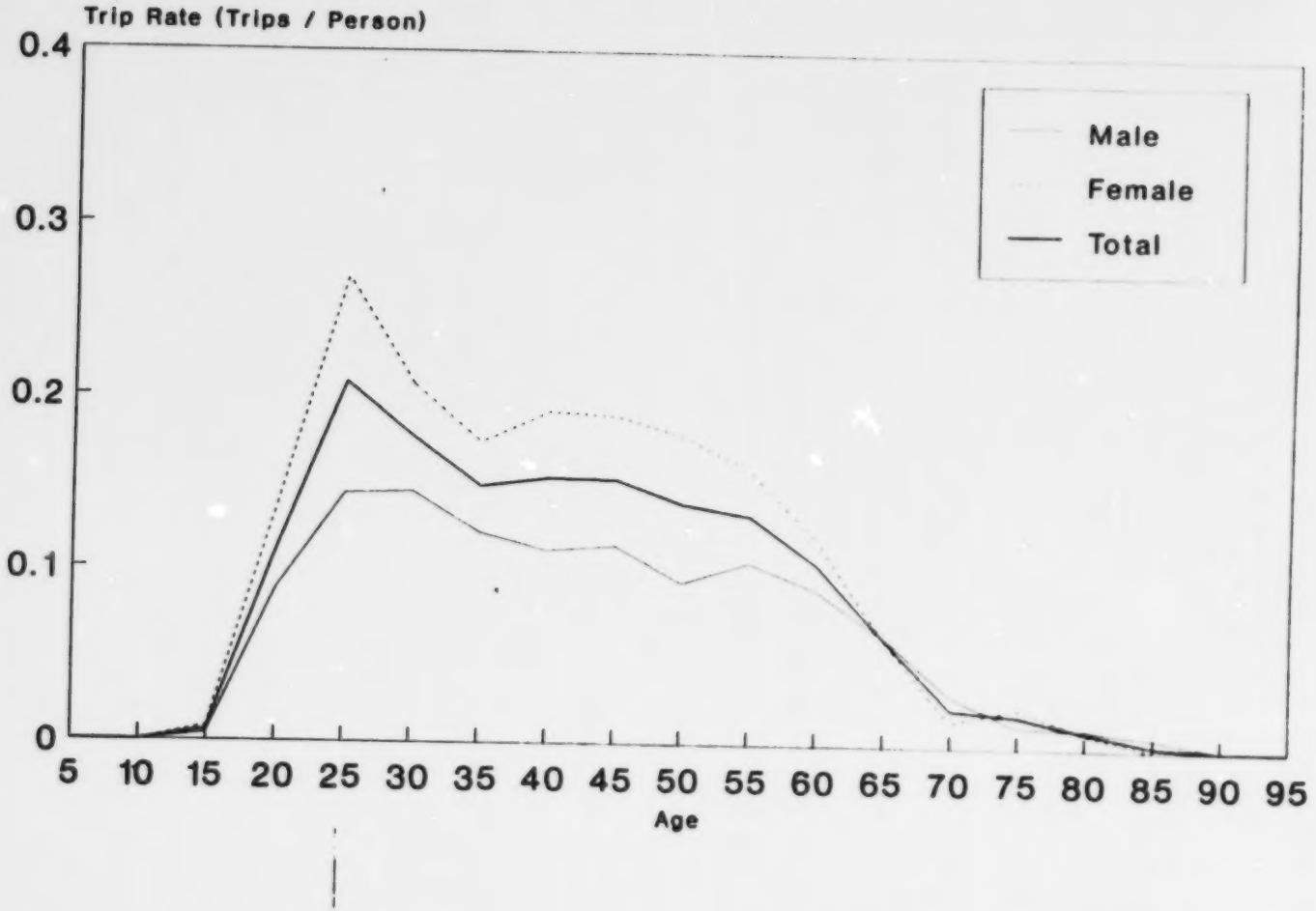
Trip Rates for Density Class 3 (Metro)
Transit Mode, 24 Hours
for Work Trips



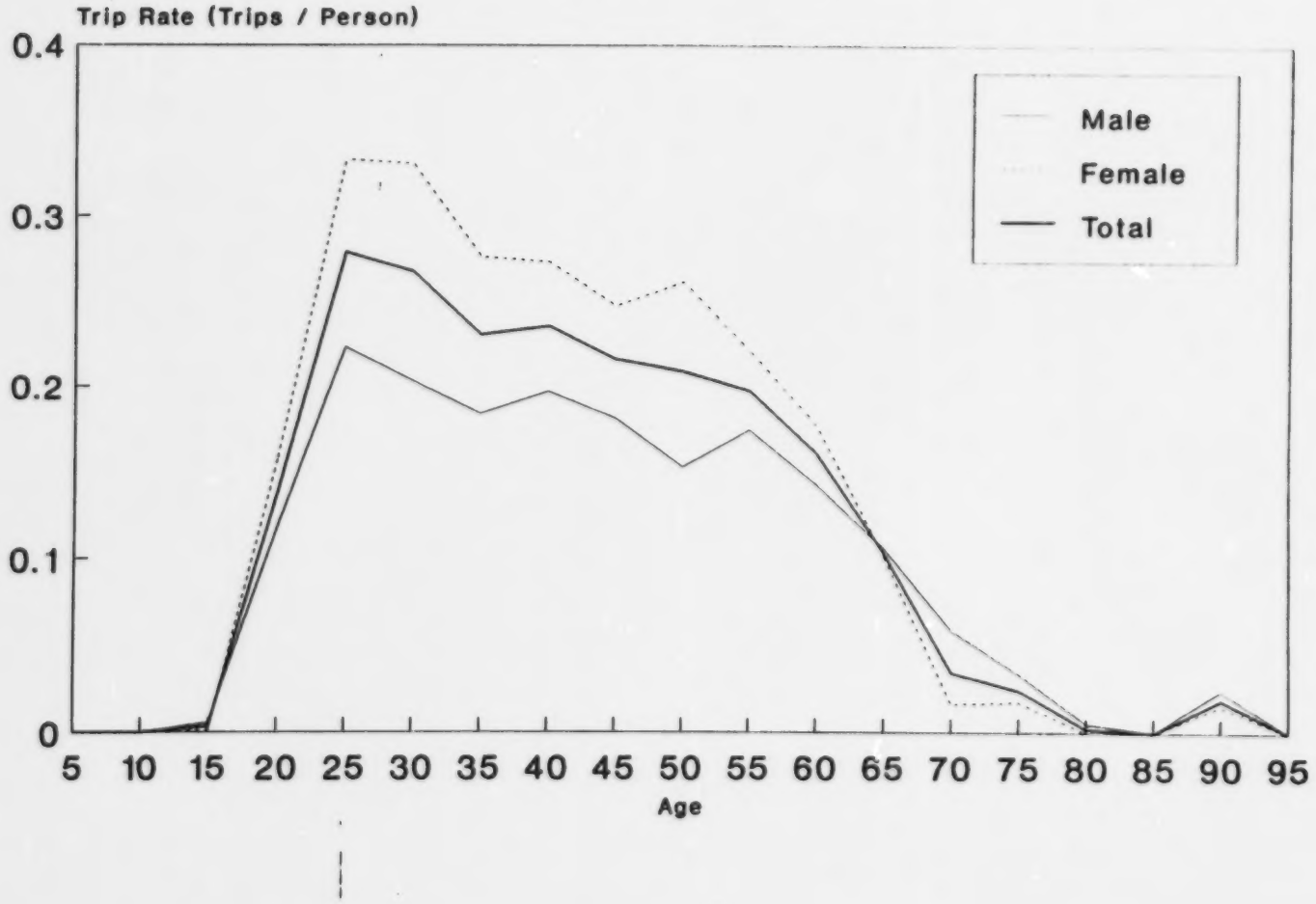
Trip Rates for Density Class 3 (Other)
Transit Mode, 24 Hours
for Work Trips



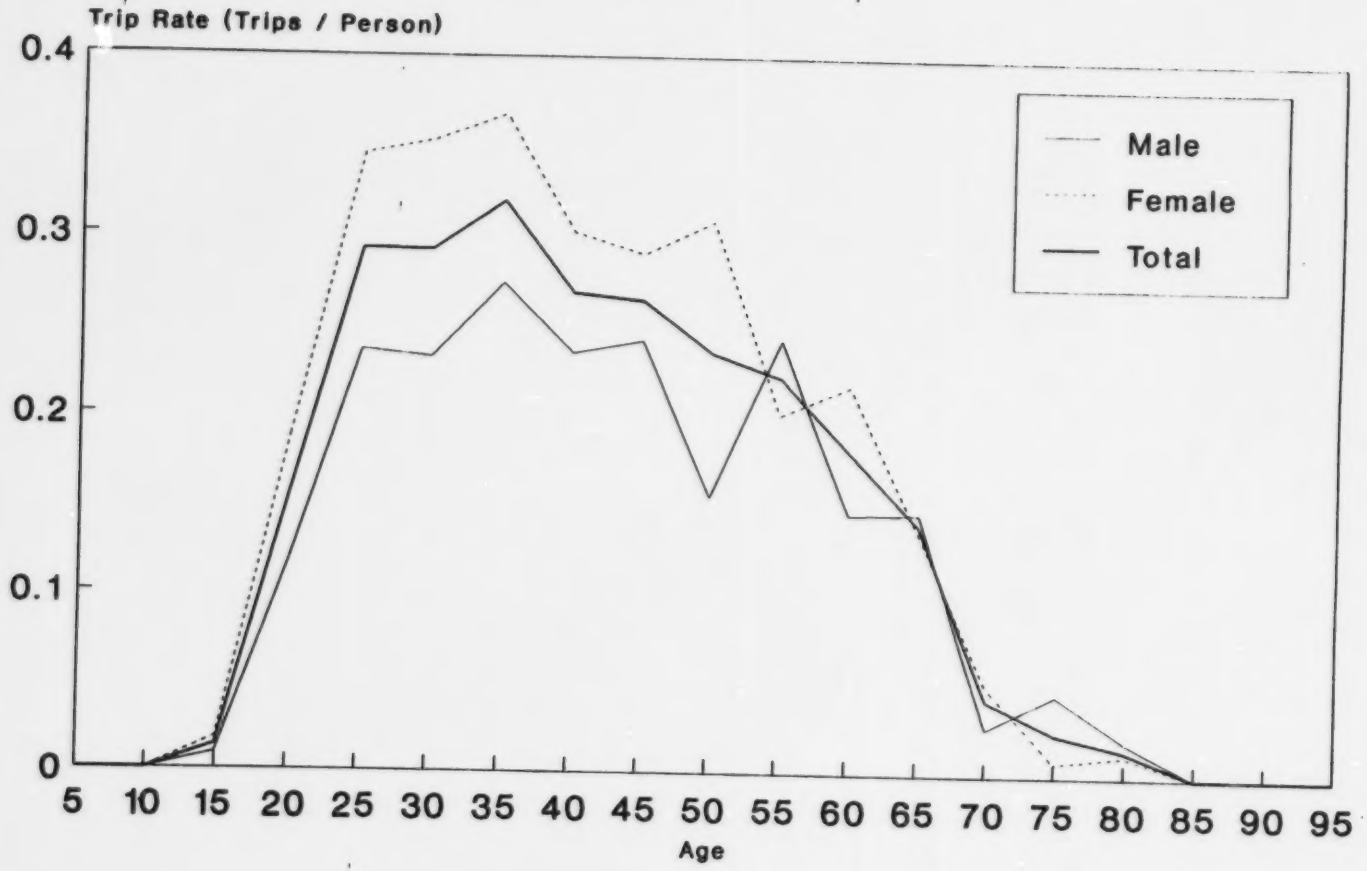
Trip Rates for Density Class 4
Transit Mode, 24 Hours
for Work Trips



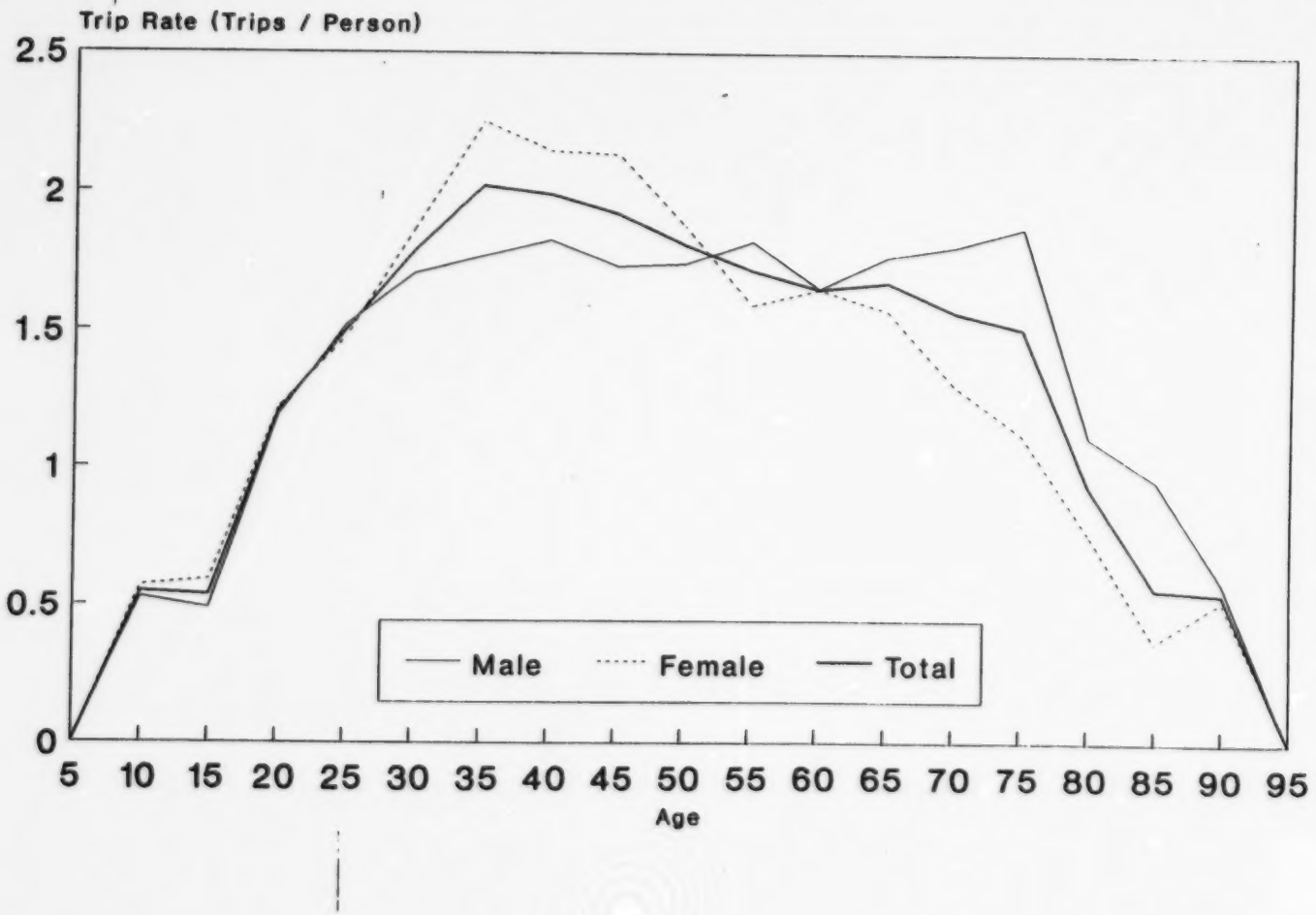
Trip Rates for Density Class 5
Transit Mode, 24 Hours
for Work Trips



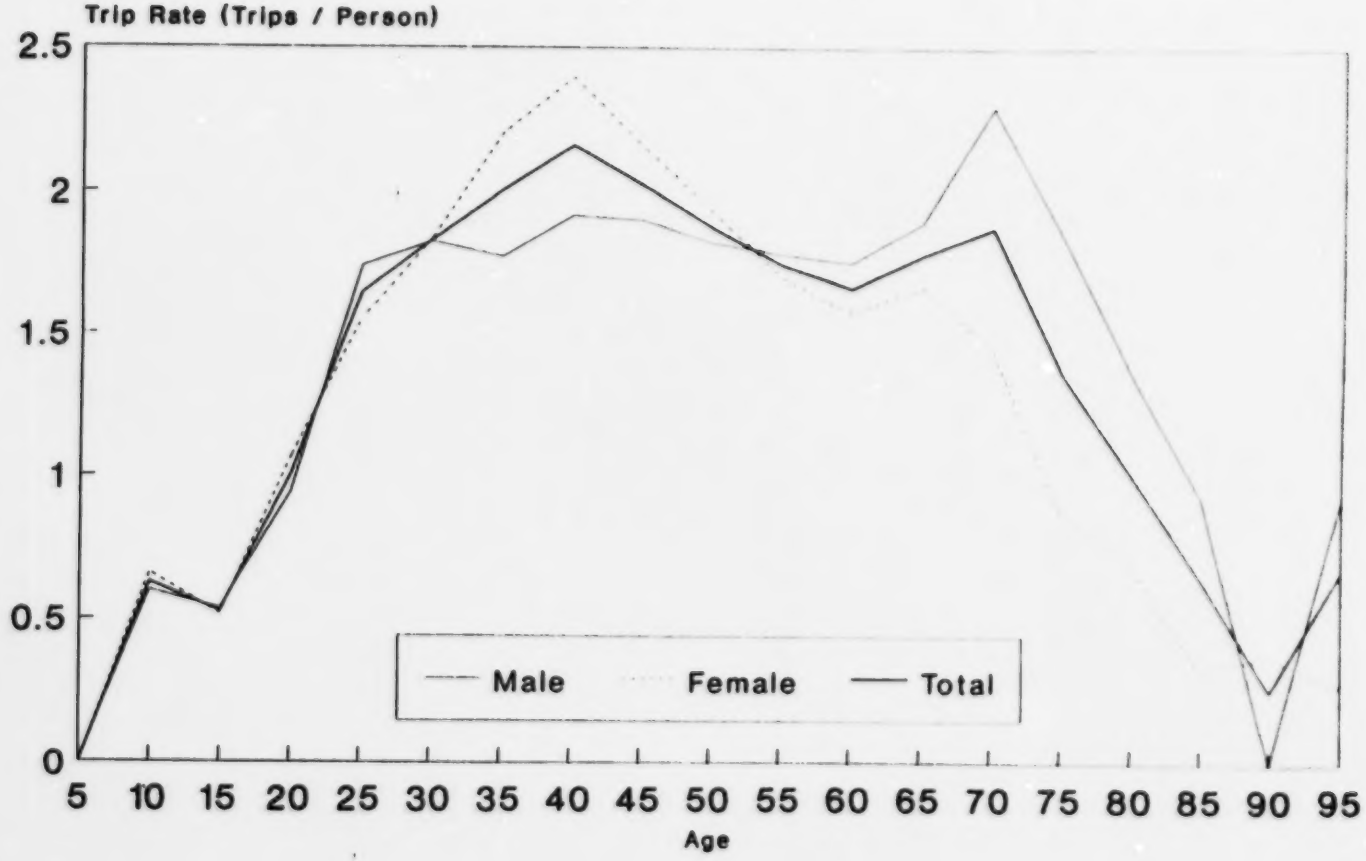
Trip Rates for Density Class 6
Transit Mode, 24 Hours
for Work Trips



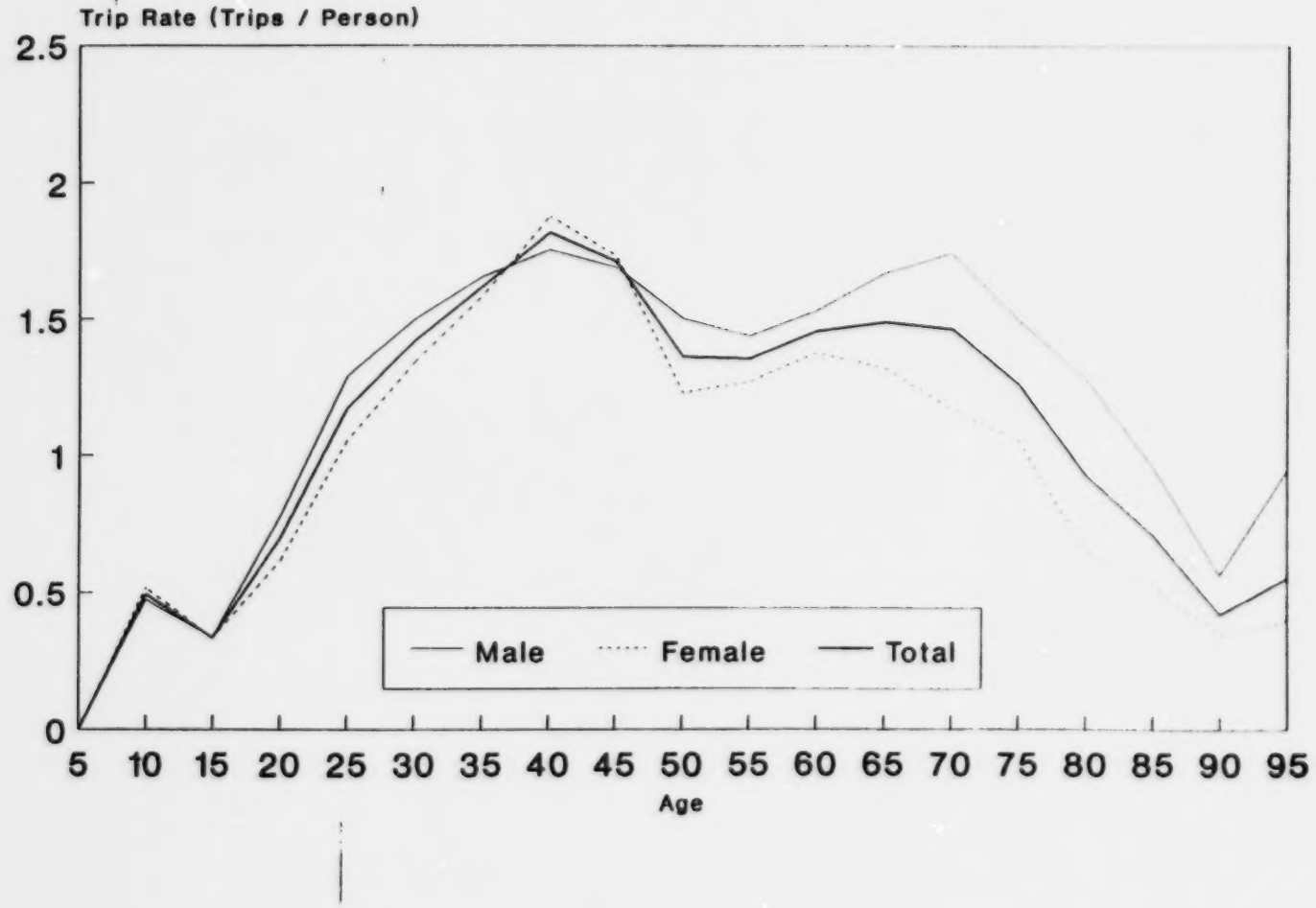
Trip Rates for Density Class 1
Auto Mode, 24 Hours
for Non-Work Trips



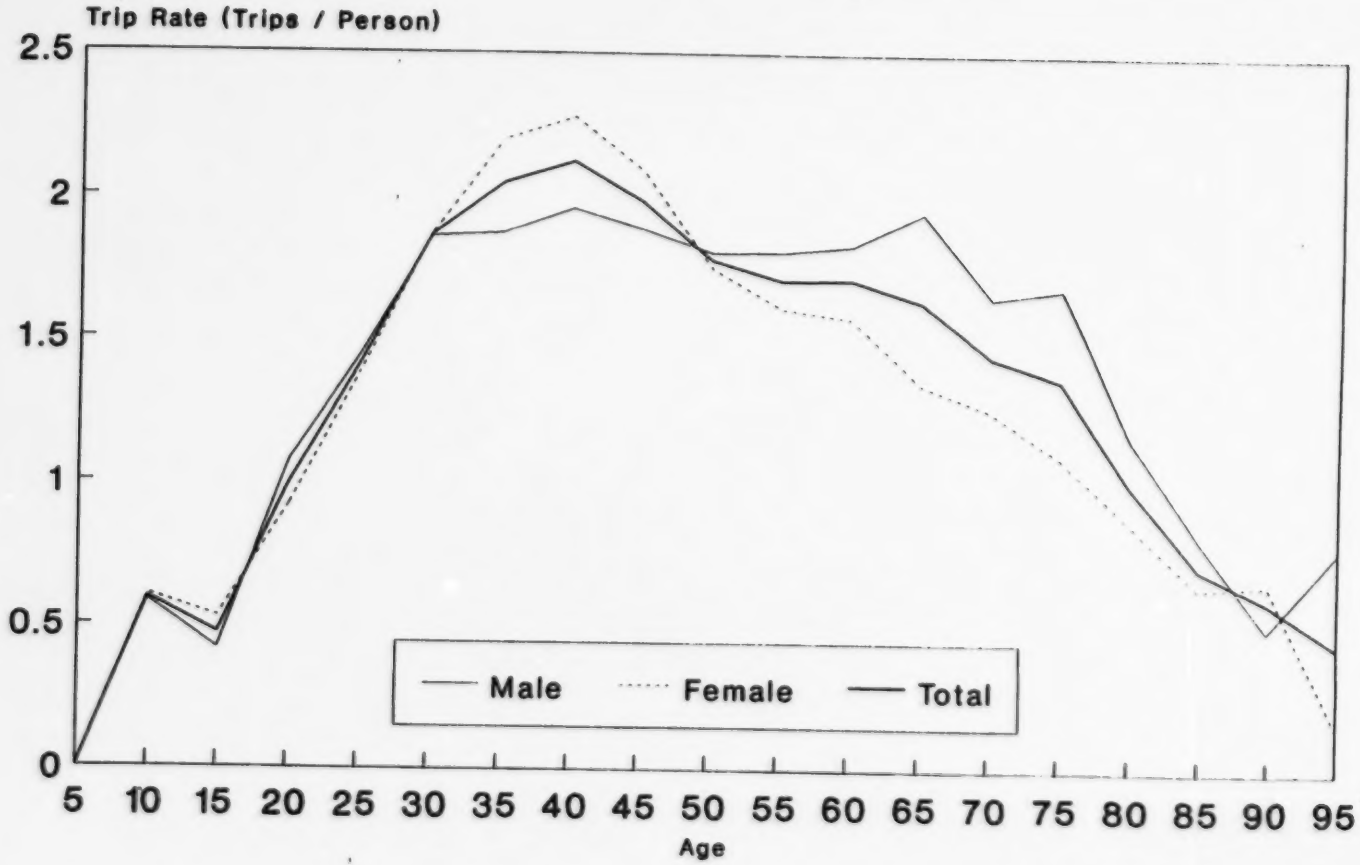
Trip Rates for Density Class 2
Auto Mode, 24 Hours
for Non-Work Trips



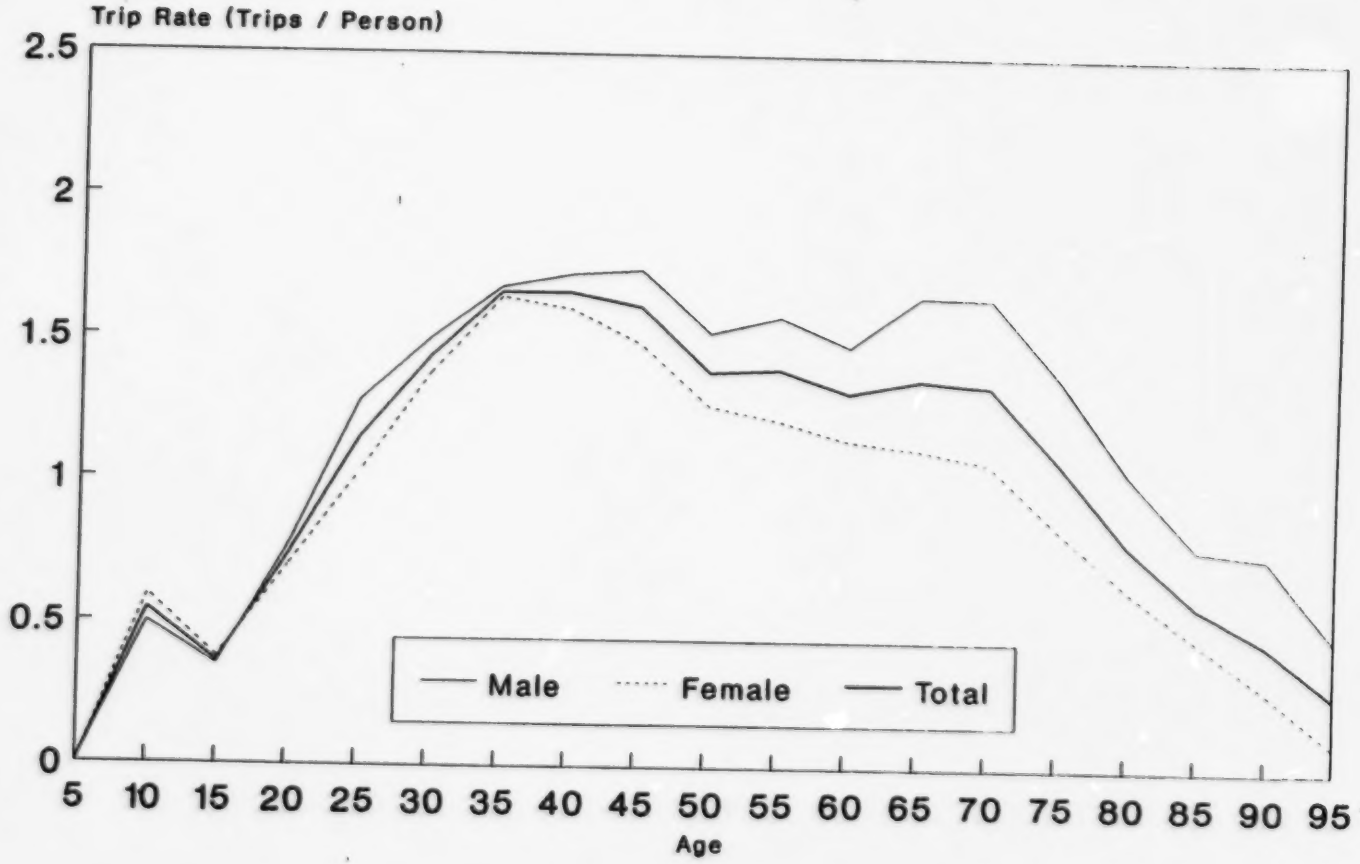
Trip Rates for Density Class 3 (Metro)
Auto Mode, 24 Hours
for Non-Work Trips



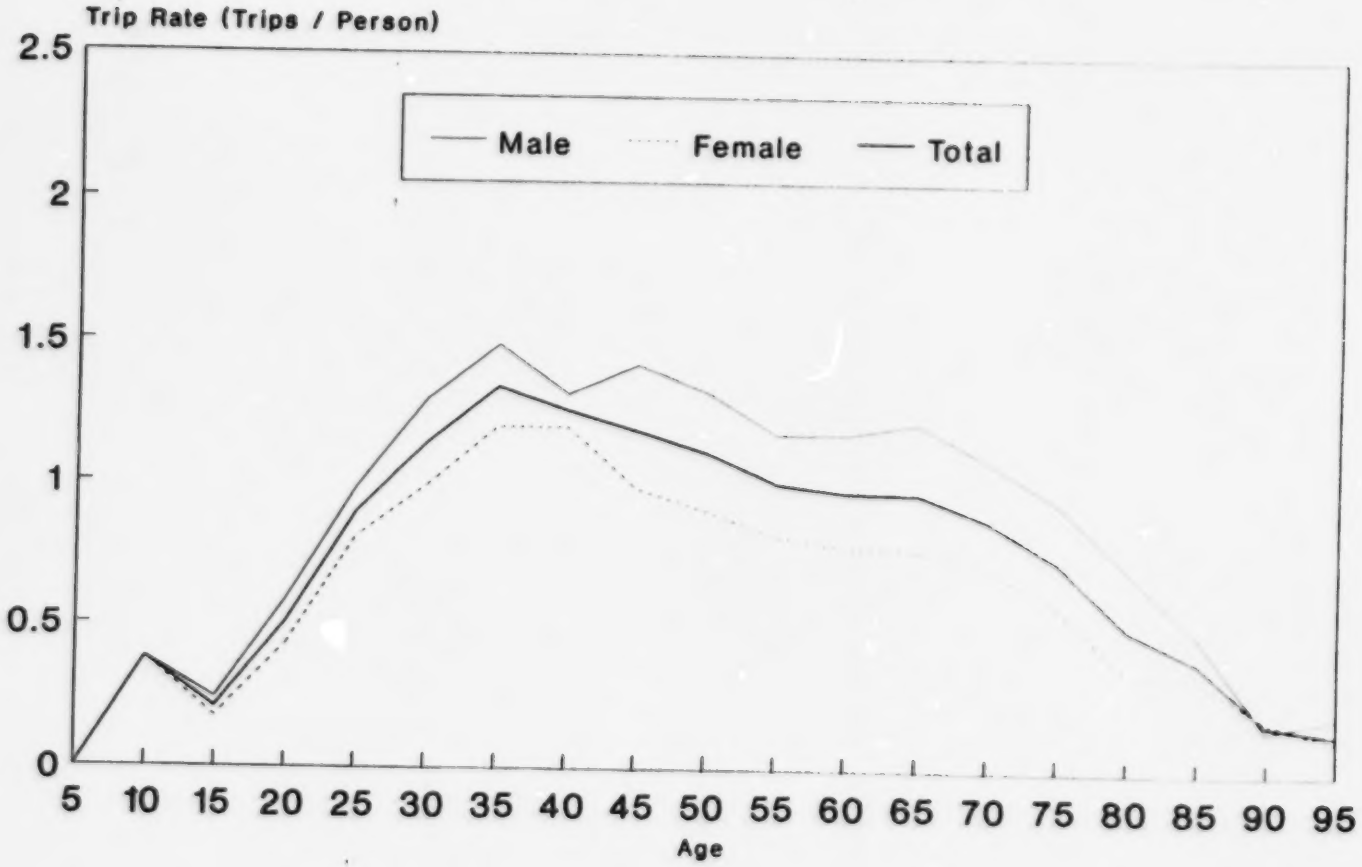
Trip Rates for Density Class 3 (Other)
Auto Mode, 24 Hours
for Non-Work Trips



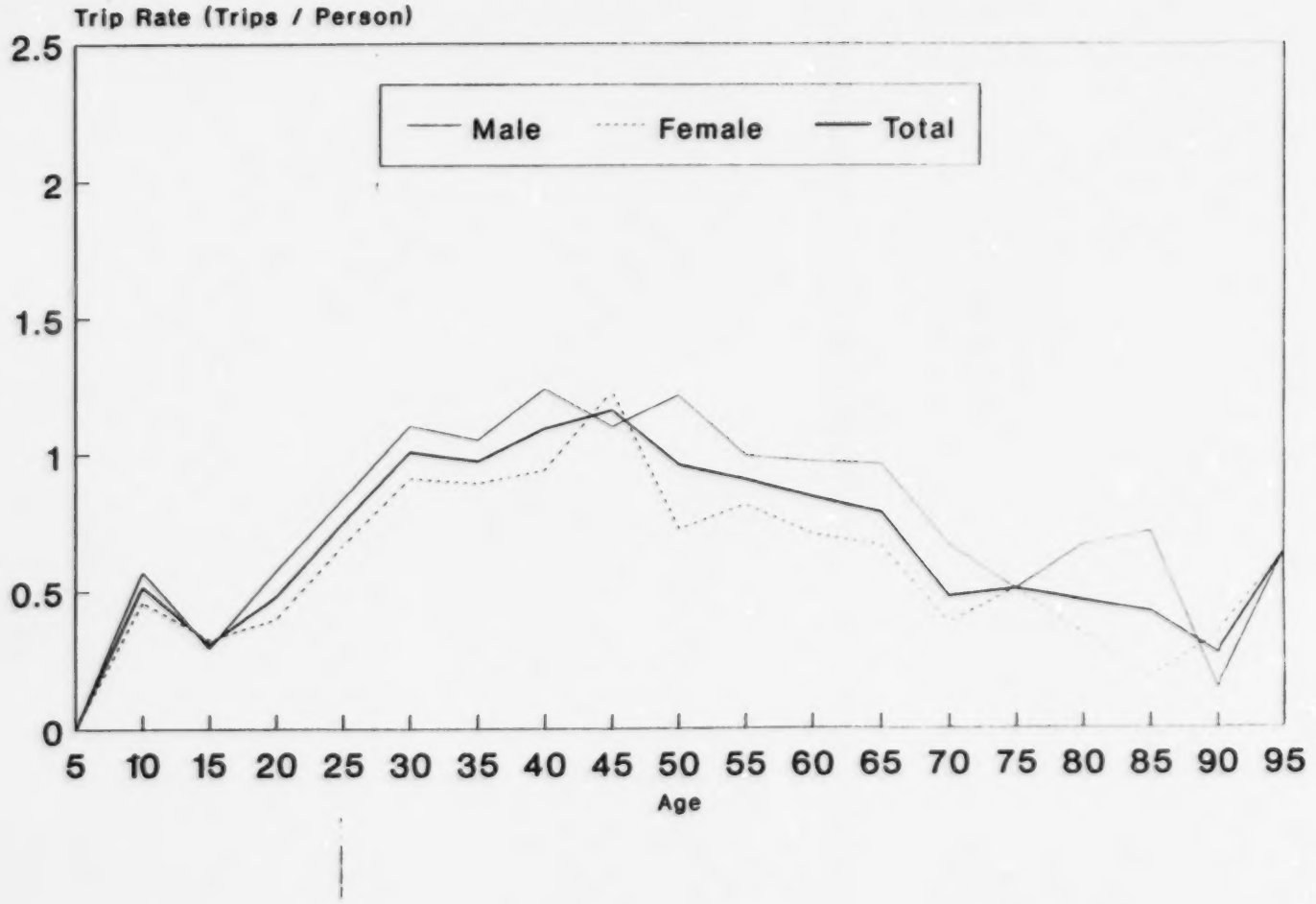
Trip Rates for Density Class 4
Auto Mode, 24 Hours
for Non-Work Trips



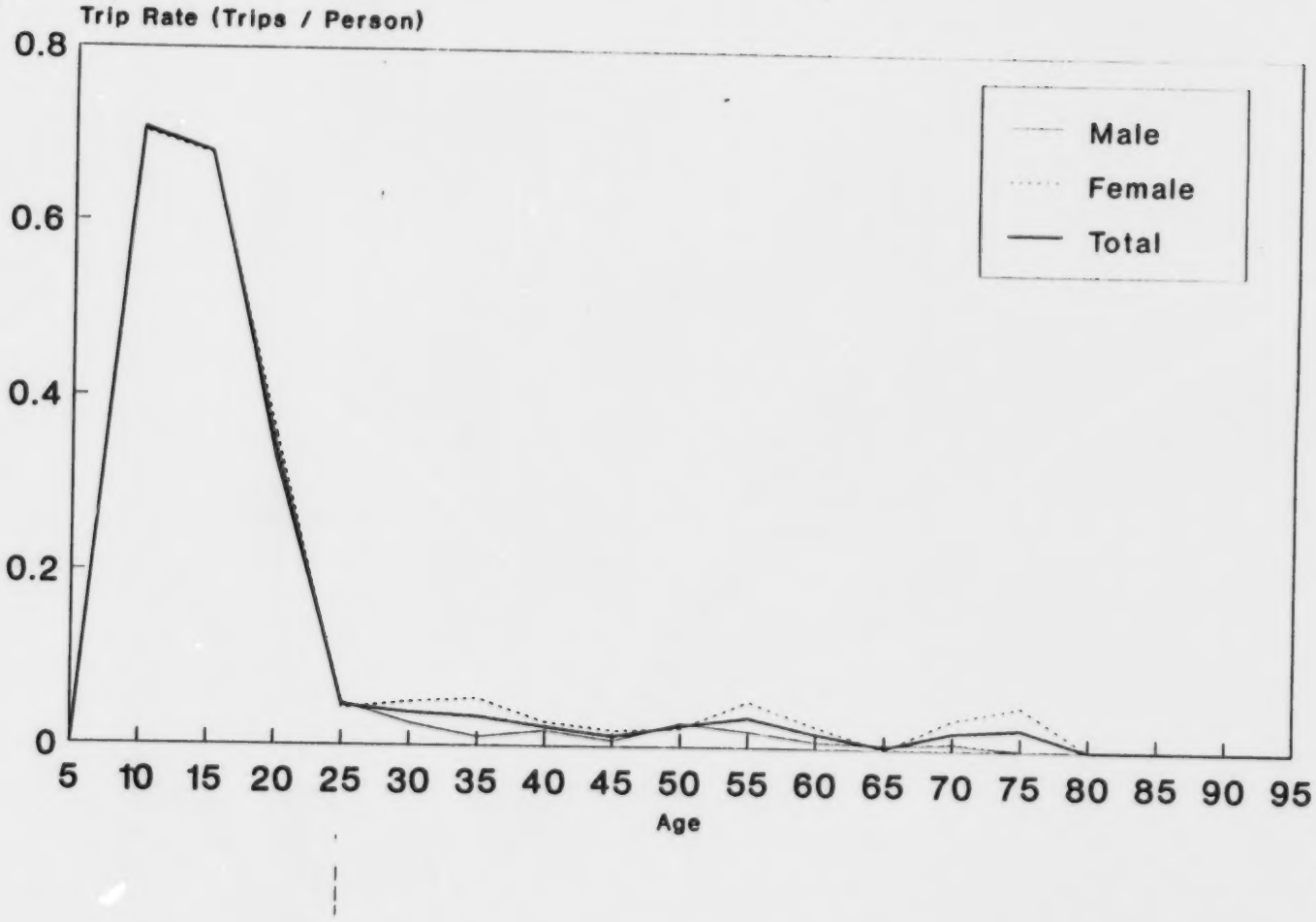
Trip Rates for Density Class 5
Auto Mode, 24 Hours
for Non-Work Trips



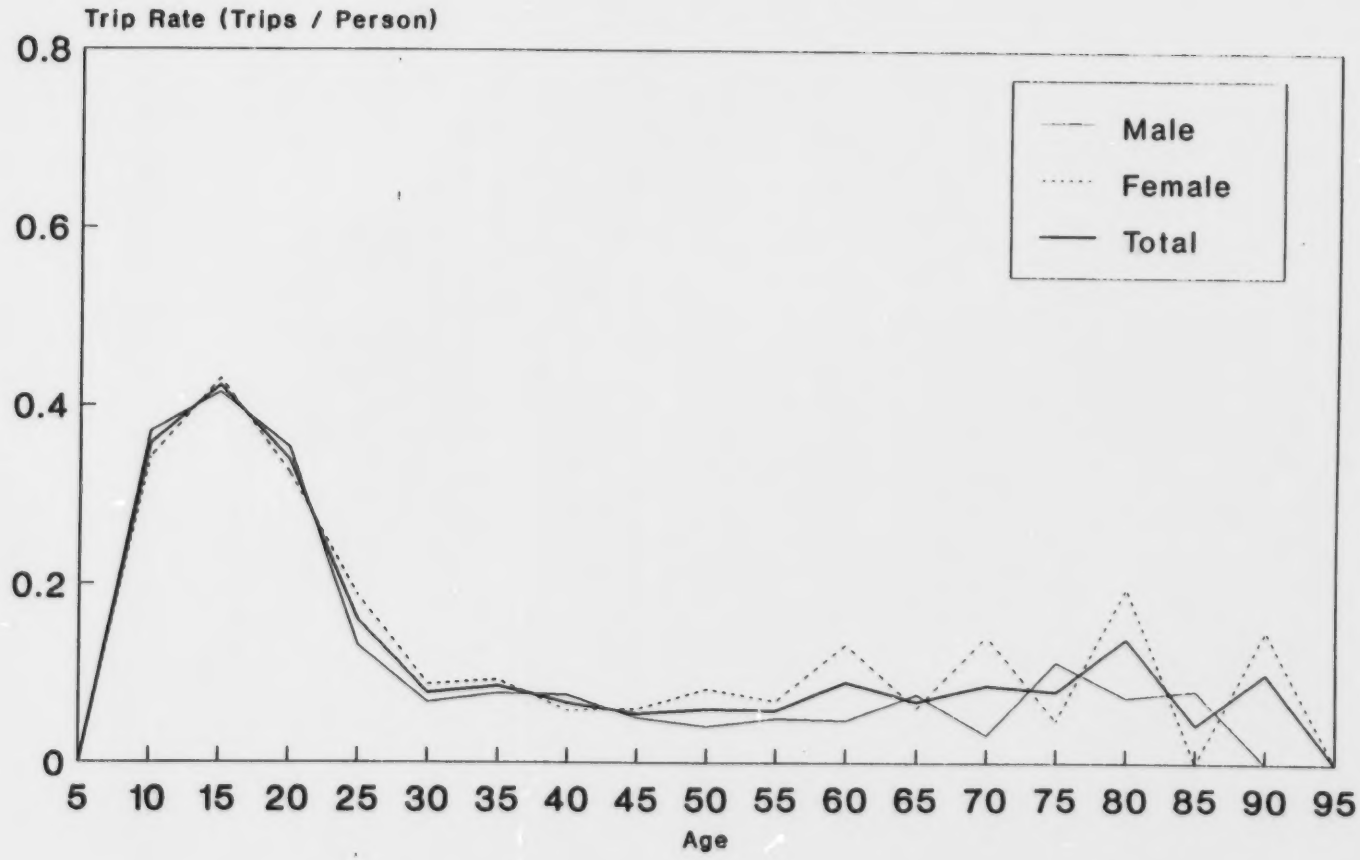
Trip Rates for Density Class 6
Auto Mode, 24 Hours
for Non-Work Trips



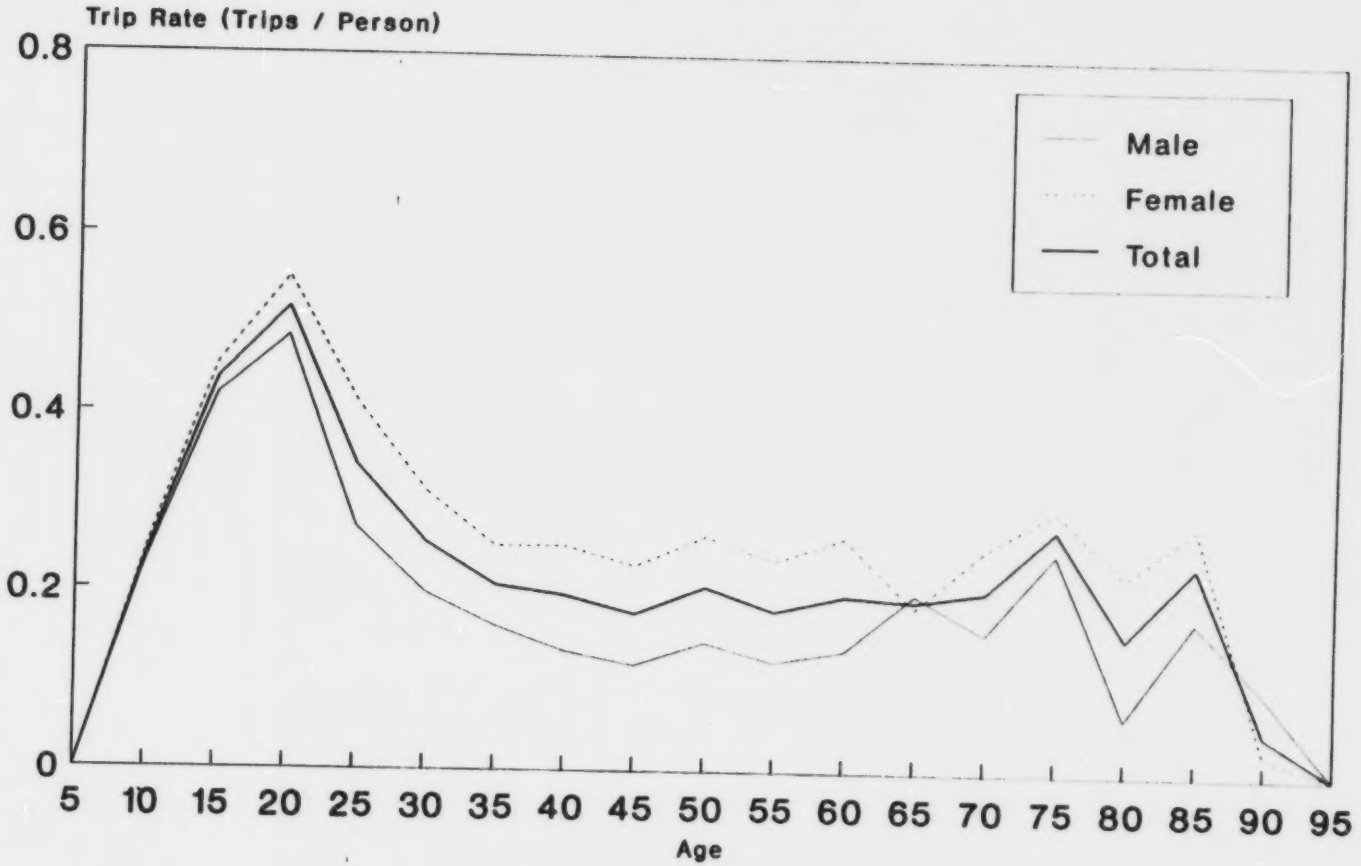
Trip Rates for Density Class 1
Transit Mode, 24 Hours
for Non-Work Trips



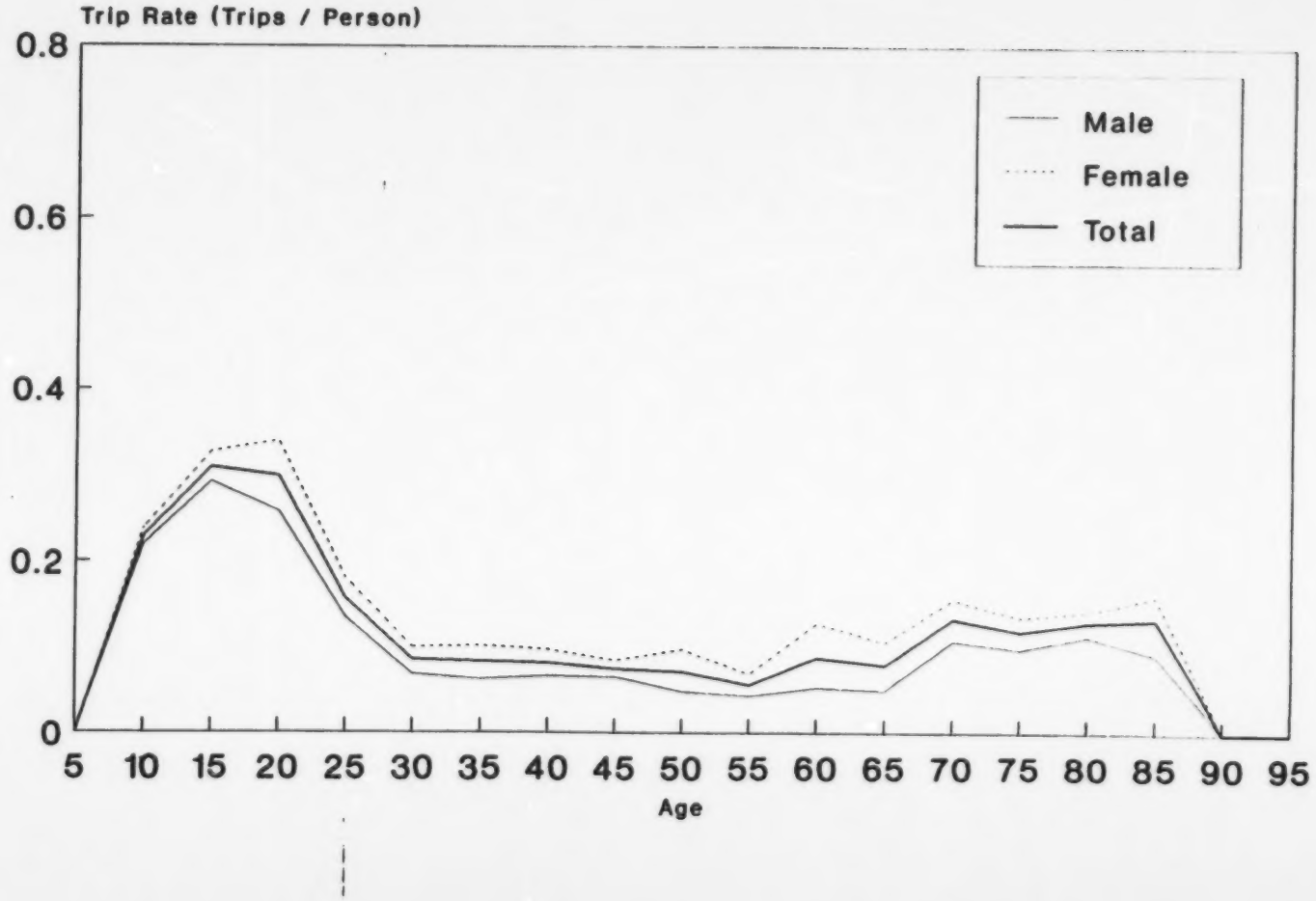
Trip Rates for Density Class 2
Transit Mode, 24 Hours
for Non-Work Trips



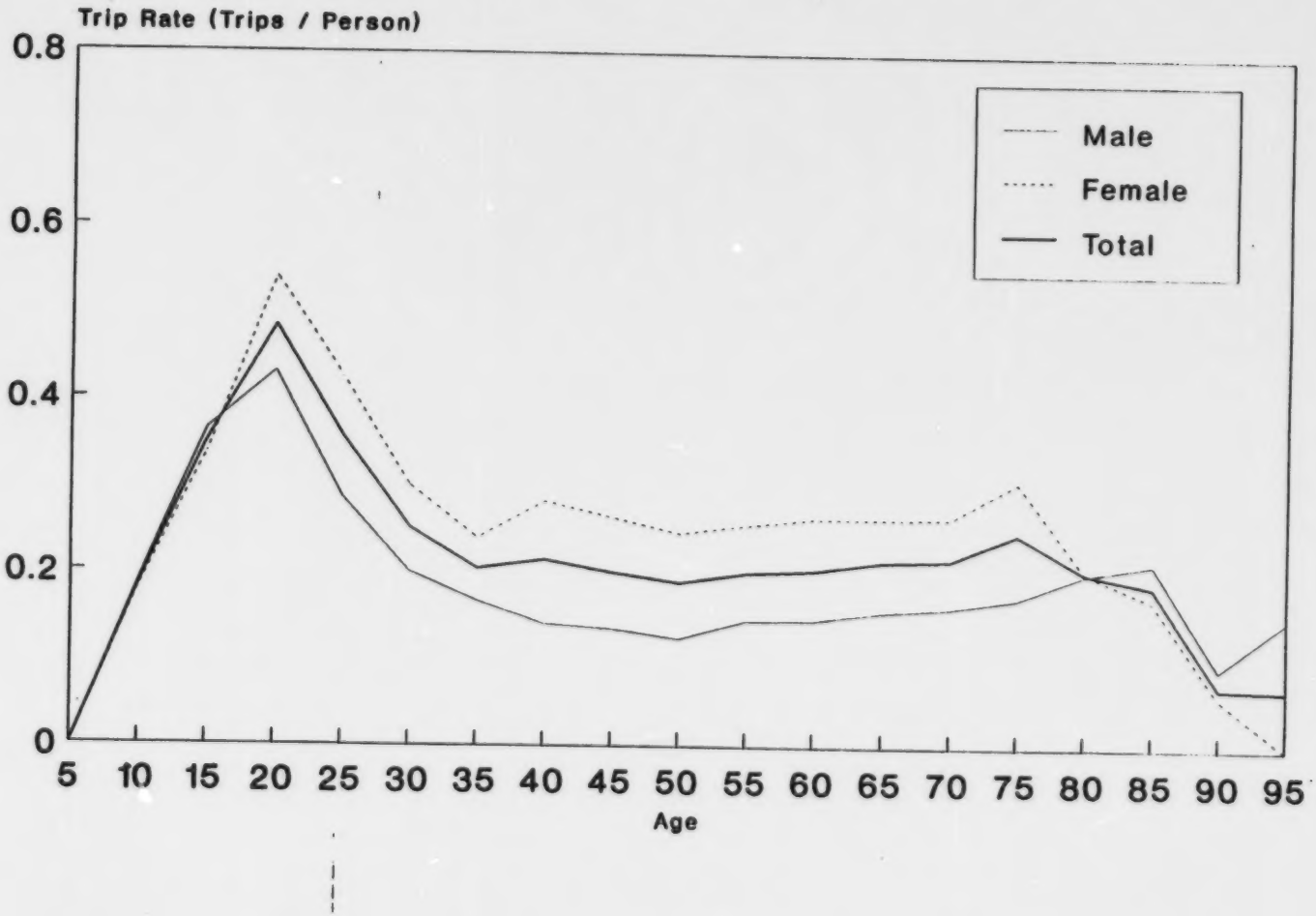
Trip Rates for Density Class 3 (Metro)
Transit Mode, 24 Hours
for Non-Work Trips



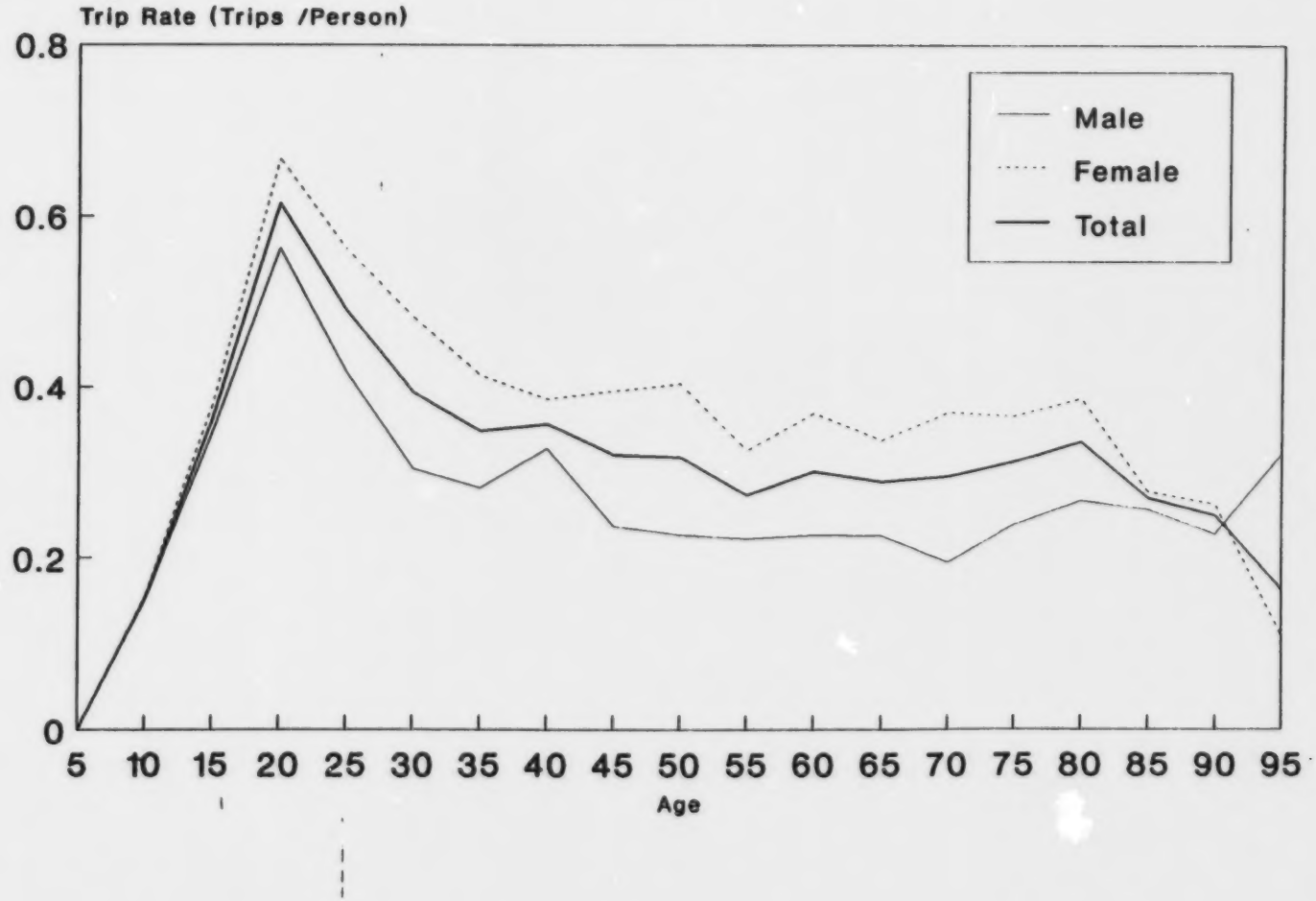
Trip Rates for Density Class 3 (Other)
Transit Mode, 24 Hours
for Non-Work Trips



Trip Rates for Density Class 4
Transit Mode, 24 Hours
for Non-Work Trips



Trip Rates for Density Class 5
Transit Mode, 24 Hours
for Non-Work Trips



Trip Rates for Density Class 6
Transit Mode, 24 Hours
for Non-Work Trips